24 MAR 2004

REC'D 20 FEB 2004

WIPO PCT

P1 1122278

THE UNITED STATES OF AMERICA

TO ALL TO WHOM THESE PRESENTS SHALL COME:

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office

February 12, 2004

THIS IS TO CERTIFY THAT ANNEXED HERETO IS A TRUE COPY FROM THE RECORDS OF THE UNITED STATES PATENT AND TRADEMARK OFFICE OF THOSE PAPERS OF THE BELOW IDENTIFIED PATENT APPLICATION THAT MET THE REQUIREMENTS TO BE GRANTED A FILING DATE.

APPLICATION NUMBER: *60/433,352*
FILING DATE: *December 13, 2002*
RELATED PCT APPLICATION NUMBER: *PCT/US03/36256*

By Authority of the
COMMISSIONER OF PATENTS AND TRADEMARKS

M. Sias

M. SIAS
Certifying Officer

PRIORITY DOCUMENT
SUBMITTED OR TRANSMITTED IN
COMPLIANCE WITH
RULE 17.1(a) OR (b)

12/13/02
JC525 U.S. PTO

12 16 02

60433352 . A [illegible]

Please type a plus sign (+) inside this box → +

PTO/SB/16 (8-00)
Approved for use through10/31/2002. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c).

JC912 U.S. PTO
60/433352

INVENTOR(S)

Given Name (first and middle [if any])	Family Name or Surname	Residence (City and either State or Foreign Country)
Peter John	Bisiules	LaGrange Park, IL, U.S.A
John H.	Coult	Chicago, IL, U.S.A
Chin	Shun-Yang	Naperville, IL, U.S.A
Joselito	de la Cruz Gavilan	Bolingbrook, IL, U.S.A

☐ *Additional inventors are being named on the _____ separately numbered sheets attached hereto*

TITLE OF THE INVENTION (280 characters max)

IMPROVEMENTS RELATING TO DIPOLE ANTENNAS

Direct all correspondence to: **CORRESPONDENCE ADDRESS**

☐ Customer Number [ ] → *Place Customer Number Bar Code Label here*

OR *Type Customer Number here*

☒ Firm or Individual Name	Eric D. Cohen, Esq.
Address	WELSH & KATZ, LTD.
Address	120 S. Riverside Plaza, 22nd Floor
City	Chicago · State IL · ZIP 60606
Country	U.S. · Telephone 312-655-1500 · Fax 312-655-1501

ENCLOSED APPLICATION PARTS *(check all that apply)*

☒ Specification *Number of Pages* 22 ☐ CD(s), Number

☒ Drawing(s) *Number of Sheets* 16 ☒ Other (specify) Unexecuted Declaration & POA

☒ Application Data Sheet. See 37 CFR 1.76

METHOD OF PAYMENT OF FILING FEES FOR THIS PROVISIONAL APPLICATION FOR PATENT *(check one)*

☐ A check or money order is enclosed to cover the filing fees

☒ The Commissioner is hereby authorized to charge filing fees or credit any overpayment to Deposit Account Number 23-0920

☐ Payment by credit card. Form PTO-2038 is attached.

FILING FEE AMOUNT ($) $160.00

The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

☒ No.

☐ Yes, the name of the U.S. Government agency and the Government contract number are: ______________________

Respectfully submitted,

SIGNATURE [signature]

Date 12/13/02

TYPED or PRINTED NAME Eric D. Cohen, Esq.

REGISTRATION NO. 38,110 *(if appropriate)*

Docket Number: 7836/88994

TELEPHONE 312-655-1500

USE ONLY FOR FILING A PROVISIONAL APPLICATION FOR PATENT

P19LARGE/REV05

CERTIFICATE OF EXPRESS MAILING

I hereby certify that this paper is being deposited with the United States Postal Service as Express Mail No. EV045460157US is an envelope addressed to Commissioner for Patents, Box Appl.'n, Washington, D.C. 20231, on this date.

Date: December 13, 2002

WELSH & KATZ, LTD.

Application Data Sheet

Inventor Information

Inventor One Given Name:	Peter John
Family Name:	Bisiules
Postal Address Line One:	1427 Blanchan
City:	LaGrange Park
State or Province:	IL
Postal or Zip Code:	60526
Citizenship Country:	U.S.A
Inventor Two Given Name:	John H.
Family Name:	Coult
Postal Address Line One:	1129 W. Wellington Ave., Ste. 100
City:	Chicago
State or Province:	IL
Postal or Zip Code:	60657
Citizenship Country:	U.S.A
Inventor Three Given Name:	Chin
Family Name:	Shun-Yang
Postal Address Line One:	5 S 270 Glenoban Drive
City:	Naperville
State or Province:	IL
Postal or Zip Code:	60563
Citizenship Country:	U.S.A
Inventor Four Given Name:	Joselito
Family Name:	de la Cruz Gavilan
Postal Address Line One:	1532 Parkside Drive
City:	Bolingbrook
State or Province:	IL
Postal or Zip Code:	60490
Citizenship Country:	U.S.A

Correspondence Information:

Name Line One:	Welsh & Katz, Ltd.
Name Line Two:	Eric D. Cohen, Esq.
Address Line One:	120 S. Riverside Plaza
Address Line Two:	22nd Floor
City:	Chicago
State or Province:	Illinois
Postal or Zip Code:	60606

Telephone Number:	312-655-1500
Fax:	312-655-1501

Application Information:

Filing Date:	12/13/02
Title Line One:	IMPROVEMENTS RELATING TO DIPOLE ANTENNAS
Total Drawing Sheets:	16
Formal Drawings:	No
Application Type:	Provisional
Docket Number:	7836/88994
Small Entity:	No

Assignee Information:

Assignee:	Andrew Corporation
Postal Address Line One:	10500 W. 153rd Street
City:	Orland Park
State or Province:	Illinois
Postal or Zip Code:	60462

Representative Information

Registration Number One::	24,003
Registration Number Two::	22,839
Registration Number Three::	28,903
Registration Number Four::	27,429
Registration Number Five::	25,060
Registration Number Six::	22,053
Registration Number Seven::	27,466
Registration Number Eight::	29,434
Registration Number Nine::	29,054
Registration Number Ten::	29,381
Registration Number Eleven::	34,044
Registration Number Twelve::	27,600
Registration Number Thirteen::	34,137
Registration Number Fourteen::	39,724
Registration Number Fifteen::	37,963
Registration Number Sixteen::	41,050
Registration Number Seventeen::	34,177
Registration Number Eighteen::	40,687
Registration Number Nineteen::	38,110

IMPROVEMENTS RELATING TO DIPOLE ANTENNAS

FIELD OF THE INVENTION

The present invention relates to a folded dipole, a dipole box, an antenna incorporating an array of dipole boxes, a method of manufacturing a dipole, and an electrically insulating element for retaining together a pair of dipoles.

BACKGROUND OF THE INVENTION

In some wireless communication systems, single band array antennas are employed. However in many modern wireless communication systems network operators wish to provide services under existing mobile communication systems as well as emerging systems. In Europe GSM and DCS1800 systems currently coexist and there is a desire to operate emerging third generation systems (UMTS) in parallel with these systems. In North America network operators wish to operate AMPS/NADC, PCS and third generation systems in parallel.

As these systems operate within different frequency bands separate radiating elements are required for each band. To provide dedicated antennas for each system would require an unacceptably large number of antennas at each site. It is thus desirable to provide a compact antenna within a single structure capable of servicing all required frequency bands.

Base station antennas for cellular communication systems generally employ array antennas to allow control of the radiation pattern, particularly down tilt. Due to the narrow band nature of arrays it is desirable to provide an individual array for each frequency range. When antenna arrays are interleaved in a single antenna structure the radiating elements must be arranged within the physical geometrical limitations of each array whilst minimising undesirable electrical interactions between the radiating elements.

US 6211841 discloses a dual band cellular base station antenna in which a high frequency band array of cross dipoles is interleaved with a low frequency band array of cross dipoles.

US 6333720 discloses a dual polarized dual band antenna. An array of two low frequency band dipole squares are mounted above a ground plane. Dipole feeds angle outwardly from the centre of each group to form a dipole square. The high band radiating elements consist of an array of three cross dipoles. A cross dipole is provided at the centre of each dipole square and one cross dipole is provided between the dipole squares.

US 4434425 discloses an arrangement of concentric dipole squares suitable for receiving radiation concentrated by a parabolic reflector antenna. The outer ring consists of vertically and horizontally polarised dipole pairs whereas the inner dipole square consists of dipole pairs having slant 45 polarization. The arrangement provides a common phase centre for receiving radiation from a parabolic reflector.

US 4555708 discloses a satellite navigation antenna for producing radiation having circular polarization.

It is desirable to provide a multi-band antenna that is compact, easy to manufacture and inexpensive, having good isolation, appropriate beam width, minimal grating lobes and a good cross polarization ratio.

EXEMPLARY EMBODIMENT

According to one exemplary embodiment there is provided a folded dipole having a dipole axis and a pair of arms which together have a profile which is concave on one side and convex on the other when viewed along the dipole axis.

According to a further exemplary embodiment there is provided a dipole box comprising two or mor folded dipoles arranged around a central region, each folded dipole having a dipole axis and a pair of arms which togeth r hav a profile which is concav on one side and convex on th other when vi wed along the dipole axis.

It should be noted that the term "box" is used herein as a generic term including (but not limited to) circular and square arrangements.

A further exemplary embodiment provides a dipole box comprising two or more dipoles arranged end to end around a central region, wherein the ends of adjacent dipoles are retained together by electrically insulating retaining elements.

A further exemplary embodiment provides an antenna comprising:

a first module comprising an outer box of two or more dipoles arranged around a first central region, and an inner box of two or more dipoles located in the first central region concentrically with the outer box; and

a second module comprising an outer box of two or more dipoles arranged around a second central region which is spaced from the first region, and an inner box of two or more dipoles located in the second central region concentrically with the outer box.

A further exemplary embodiment provides a method of manufacturing a folded dipole having a dipole axis and a pair of arms which together have a profile which is concave on one side and convex on the other when viewed along the dipole axis, the method comprising forming the pair of arms from a sheet of conductive material.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings which are incorporated in and constitute part of the specification, illustrate embodiments of the invention and, together with the general description of the invention given above, and the detailed description of the embodiments given below, serve to explain the principles of the invention.

Figure 1	shows a plan view of a panel antenna having an array of two dipole rings;
Figure 2	shows an end view of the antenna of figure 1;
Figure 3	shows a plan vi w of a multi-band antenna having an array of dipole rings and an array of cross dipol s;
Figure 4	shows an end view of the antenna of figure 3;

Figure 5 shows an antenna according t a third embodiment having an array of ring dipoles and three linear arrays of cross dipoles;

Figure 6 shows a fourth embodiment, similar to the third embodiment, but including cross dipoles between dipole rings;

Figure 7 shows a fifth embodiment including an array of dipole rings having three cross dipoles within each ring;

Figure 8 shows a sixth embodiment in which each of the dipole rings of a first array of ring dipoles are located concentrically within each dipole ring of a second array of dipole rings;

Figure 9 shows a seventh embodiment, similar to the embodiment of figure 6, in which high frequency dipole rings are provided between low frequency dipole rings;

Figure 10 shows an antenna module in which the inner dipole box is a dipole square formed of linear folded dipoles;

Figure 11 shows an antenna module in which the inner dipole box is a dipole square formed of bent folded dipoles;

Figure 12 shows an embodiment including a first array of bent folded dipole squares and three linear arrays of cross dipoles;

Figure 13 shows an embodiment in which the cross dipoles are in a square rather than diamond formation within each dipole square;

Figure 14 shows an antenna module consisting of two concentric bent folded dipole squares;

Figure 15 shows an antenna module, similar to the embodiment of Figure 14, in which the inner dipole square is formed of linear folded dipoles rather than bent folded dipoles;

Figure 16 shows an antenna module in which the inner dipole box is formed of curvilinear folded dipoles rather than bent folded dipoles;

Figure 17 shows an antenna module including a first dipole square formed of linear folded dipoles and a second dipole square formed of bent folded dipoles;

Figure 18 shows an antenna module in which the inner dipole square of Figure 17 is replaced by a ring of curvilinear folded dipoles;

Figure 19 shows an alternativ dipole ring consisting of two semicircular folded dipoles.

Figur 20	shows an array of dipole rings of th type sh wn in figure 19.
Figure 21	shows a preferred embodiment;
Figure 22	shows a perspective view of a single antenna module;
Figure 23	shows a plan view of the module of figure 22;
Figure 24	shows one of the cross dipoles of figure 22 viewed from the centre of the module;
Figure 25	shows a side view of the module of figure 22;
Figure 26	shows a schematic view of the antenna feed network for feeding the antenna of figure 21;
Figure 27	shows a plan view of a clip with a dipole arm being inserted;
Figure 28	shows an end view of the clip; and
Figure 29	shows a cross-section through the clip along a line A-A in figure 27.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

Figure 1 shows a plan view of an array of ring dipoles according to a first aspect of the invention. First and second dipole rings 1 and 2 are provided in spaced apart relation above ground plane 3. Each dipole ring consists of four folded dipoles, such as folded dipoles 4, 5, 6 and 7 arranged in a ring.

Each dipole 4, 5, 6, 7 is constructed identically and an exemplary dipole 4 will be described. The dipole 4 has a pair of arms 8,9 which are generally curvilinear in shape and lie in a plane parallel to the plane of ground plane 3 (ie. a plane orthogonal to the axis of propagation of the dipole 4). The centre of curvature of the arms 8,9 lies at the centre of the ring 1. In this embodiment each folded dipole 4, 5, 6, 7 extends over about a quarter circle so that a ring of folded dipoles 4, 5, 6, 7 forms an approximately circular dipole ring 1. It can be seen that the dipoles 4-7 are generally concavo-convex as viewed along their axes of propagation. That is, they have a convex outer side and a concave inner side.

The dipoles are arranged as orthogonally opposed pairs. Folded dipoles 4 and 7 form a first pair offset by + 45° with respect to the vertical and folded dipoles 5 and 6 form a second pair, orthog nal to dipoles 4 and 7, ffset by - 45° with respect to vertical. This arrang ment allows the ant nna to propagate and receive dual

polarized slant 45 radiation. As shown in figure 2, feeds 11 and 12 support folded dipole 5 and feeds 13 and 14 support folded dipoles 7. Feeds 11, 12, 13 and 14 are connected to a printed circuit board (PCB) feed network 15 on top of the ground plane 3. The PCB feed network 15 is shown in figure 2 but omitted from Figure 1 for clarity. In other embodiments (not shown) the PCB feed network 15 may be replaced by an air suspended microstrip or a cable.

The dipole arms and feeds are formed by stamping from a single sheet of metal and folding the feeds by 90°.

Referring now to figure 3, a dual band embodiment is shown in which a low frequency array of dipole rings 20, 21 and 22 has the same construction as the dipole rings shown in figures 1 and 2. A more detailed description of a five element antenna (otherwise identical to the antenna of figure 3) is given in figures 21-29. Each ring defines an inner region within the ring providing a large area to accommodate further radiating elements of a high frequency array. The radiating elements of such further array may be dipole elements, patches or any other desired elements. In this embodiment a high frequency array of cross dipoles 23-28 is provided within the dipole rings. The high frequency array operates in a high frequency band having a mid-point frequency higher than the mid-point frequency of operation of the low frequency dipole ring array. The cross dipole array also provides slant 45 dual polarization.

The arrangement shown in figures 3 and 4 has a number of desirable characteristics. Firstly, a dual band antenna is provided that is compact as the radiating elements of both bands can be contained within the same area. Secondly, the arrangement has good symmetry resulting in good isolation characteristics. The fact that no radiating element is positioned in the gaps between the dipole rings results in good symmetry and thus good isolation. The geometrical arrangement further allows the high frequency dipoles 23-28 to be evenly spaced, thus minimising grating lobes.

The nd view shown in figure 4 is similar to the end view for the first mbodiment shown in figure 1 except that a cross dip le is shown. Cross dipole 28 has arms 31 and 32 supported by feeds 33 and 34 respectiv ly. The arms 31 and 32 ar inclined

downwardly towards ground plane 35. The arms of the cross dipoles preferably incline towards ground plane 35 by about 20°. The geometry allows PCB feed network 36 to be kept relatively compact with one PCB feeding each dipole ring and elements within the ring.

Referring now to figure 5 a third embodiment is shown which is a modification of the embodiment shown in figure 3. Like integers have been given like numbers. In this embodiment two additional arrays of cross dipoles have been added to the embodiment shown in figure 3. A first array of cross dipoles 40, 41 and 42 is provided to the left and a second array of cross dipoles 43, 44 and 45 is provided to the right. By adjusting power division or phase shift between first array 40, 41 and 42, second array 23-28 and third array 43-45, beam width may be adjusted or azimuth steering may be provided. Various feed arrangements for adjusting beam width or effecting azimuth and/or downtilt steering are disclosed in the Applicant's PCT application no. PCT/NZ01/00137, the disclosure of which is hereby incorporated by way of reference. Such techniques may also be utilised with the multi array embodiments described hereafter. Beam width/angle control may be effected using a remotely controlled electromechanical motor (not shown) mounted on the back of the antenna ground plane, as described in more detail in PCT/NZ01/00137 and PCT/NZ95/00106, the disclosure of which is also hereby incorporated by way of reference.

The arrangement shown in figure 5 has good symmetry with no radiating element at the middle of any dipole ring and no radiating elements between dipole rings. This results in good isolation characteristics. Further, the cross dipoles 23-28 of the main array are evenly spaced to minimize grating lobe potential.

The fourth embodiment of figure 6 is a modification of the third embodiment shown in figure 5 and only the additional elements have been referenced. In this embodiment additional cross dipoles 50-53 are provided in the outer cross dipole arrays. These enhance control of beam width and azimuth beam steering and reduce the effect of grating lobes in the outer cross dipole arrays.

Figure 7 shows a fifth mb diment, similar to th second embodiment shown in figures 3 and 4, in which three cross dipoles are provided within each dipole ring instead of two. Like integers have been given like numbers to those in figure 3. In this embodiment three linear arrays of cross dipoles 55, 58 and 61;-54, 57 and 60; and 56, 59 and 62 are provided. Each array is evenly spaced to reduce grating lobes. All of the cross dipoles are located within the dipole rings and are equidistant from the centre of the ring so as to form an equilateral triangle shape which has good symmetry and thus good isolation characteristics.

Figure 8 shows a sixth embodiment comprising a first array of dipole rings for operation over a first frequency band and a second array of dipole rings 66, 67 and 68 operable over a second frequency band having a mid-frequency higher than the mid-frequency of the first frequency band. All dipole rings employ curvilinear folded dipoles of substantially quarter circle segments. The arrangement has good symmetry and thus good isolation characteristics.

The seventh embodiment shown in figure 9 is similar to the sixth embodiment shown in figure 8 except that additional high band dipole rings 69 and 70 are provided in the gaps between low frequency dipole rings 71-73. The array of high frequency dipole rings 74, 69, 75, 70 and 76 may be spaced so as to avoid grating lobes. It will be appreciated that additional high frequency band dipole rings may be placed between low frequency band dipole rings in other embodiments herein described also.

Referring now to figure 10 an antenna module is shown comprising a dipole square 80 oriented to provide slant 45 polarization, and a ring 83.

Figure 11 shows an antenna module, which is a variant of the module shown in figure 10, in which the dipole squares 80 is replaced with a dipole square 86 consisting of four bent folded dipoles. Each bent folded dipole has a pair of straight arms disposed at about 90° to one another and meeting at a corner. Thus the bent folded dipoles each have a generally V-shaped profile as viewed along the axis of the dipol .

Figure 12 shows an embodiment in which a low band array consists of an array of bent folded dipole squares 92, 93 and 94 and three high frequency arrays are formed by cross dipoles 95-97; 98-102, 77; and 103-105. Bent folded dipole squares 92, 93 and 94 provide a geometry that allows the squares to be closely spaced together whilst providing a large inner region to accommodate high frequency radiating elements. The arrangement provides two dual polarization slant 45 antennas for operation over different frequency bands. The symmetry of the arrangement provides good isolation.

The embodiment shown in figure 13 employs a square arrangement of cross dipoles within each square instead of a diamond arrangement. This results in two cross dipole arrays 106-111 and 112-117 within bent folded dipole squares 118-120.

Referring now to figure 14 an antenna module is shown consisting of a low frequency band dipole square 121 and a high frequency band dipole square 124. The dipole squares are formed from bent folded dipoles and are arranged concentrically.

Figure 15 shows a modified antenna module in which the high frequency dipole square 127 is formed of linear folded dipoles, whilst the low frequency dipole square 130 is formed of bent folded dipoles.

Figure 16 shows a further variant in which the high frequency band element is a dipole ring 133 whilst the low frequency dipole square 136 is formed of bent folded dipoles. Also, the bent folded dipoles forming the dipole square 136 have truncated corners 139.

Figure 17 shows a further embodiment in which the high frequency band element is a bent folded dipole square 173 and the low frequency band element is a linear folded dipole square 170.

Figure 18 shows a further variant in which the high frequency band radiating element is a dipole ring 182 and the low frequency band radiating elements is a linear fold d dipole square 184.

Figures 10, 11, and 14-18 each show various single antenna modules, consisting of a concentric pair of dipole boxes. A dual band antenna may be constructed using a single module only. Alternatively, an array antenna may be constructed using an array of the modules of Figures 10, 11 and 14-18, with an additional high frequency radiating dipole box positioned between each module (as shown in Figure 9). The additional high frequency dipole box is required so that the centre-to-centre spacing of the high frequency elements is approximately half the centre-to-centre spacing of the low frequency elements, so that in wavelength terms the centre-to-centre spacing is approximately equal.

A further alternative dipole ring 220 is shown in Figure 19. The ring consists of two curved folded dipoles 221,222. The dipoles 221,222 are identical in construction to the dipoles 4-7 shown in Figure 1, except the dipole arms extend over a semi-circle.

A panel antenna 230 shown in Figure 20 has a ground plane 231 and three dipole rings 232-234 each consisting of two semicircular dipoles.

A preferred embodiment is shown in Figure 21. The antenna 300 has a back panel 301 carrying five identical modules 302, one of which is shown in detail in Figures 22-25. Module 302 has a dipole ring consisting of two +45° folded dipoles 303 and two -45° folded dipoles 304. Feed legs 305-308 are connected to a printed circuit board (PCB) 309 as shown. The dipole arms and feeds are formed by stamping from a single sheet of metal and folding the feed legs by 90°.

A pair of high frequency cross dipoles 310,311 is provided within the dipole ring. Each cross dipole has a +45° dipole and a -45° dipole formed as copper strips deposited on insulating boards 312,313. Each dipole is driven by a respective balun feedline deposited on the other side of the insulating board. Figure 24 is a side view of cross dipole 311 as viewed from the centre of Figure 23. Insulating board 313 carries a balun feedline 320 shown in Figure 24 which leads to a quarterwave open-circuit stub portion (hidden behind the other insulating board 312 in Figure 24). Insulating board 312 carries a balun feedline (hidden behind the other insulating board 313 in Figure 24) and a quarterwave pen-circuit stub portion 321. The balun feedline and quarterwave open-circuit stub portions couple capacitively with the

dipoles printed on the other side of the insulating board. The two balun feedlines and open-circuit portions are arranged in a typical cross over/cross under fashion.

The antenna is driven by a feed network illustrated schematically in Figure 26. The low frequency dipole rings are driven by feed network 330, and the high frequency crossed dipoles are driven by feed network 331. Each feed network has a respective pair of feedlines which input into downtilt phase shifters 332-335. Each phase shifter 332-335 has a single input feedline and five antenna output lines 341,342. A progressive phase shift is introduced on the five antenna output lines to produce variable downtilt. The degree of downtilt is controlled remotely by a controller 336 as described in more detail in PCT/NZ01/00137 and PCT/NZ95/00106. The four phase shifters 332-335 may be driven together or independently. The phase shifter 332 is connected to the ten low frequency +45° folded dipoles 303 via power splitters 337. The phase shifter 333 is connected to the ten low frequency -45° folded dipoles 304 via power splitters 338. The phase shifter 334 is connected to the ten high frequency +45° dipoles 313 via power splitters 339. The phase shifter 335 is connected to the ten high frequency -45° dipoles 312 via power splitters 340.

The power splitters 337-340 are shown in detail in Figure 23. Feedline 341 is coupled to four lines 350-353 via T-junctions 354-356. Each line 350-353 is coupled to a respective dipole feed leg 305-308. Lines 353 and 351 are longer than lines 350,352, and thus introduce a 180° phase shift between the respective pair of dipole feed legs. Feedline 342 is coupled to a pair of lines 360,361 via T-junction 362. Each line 360,361 is coupled to a respective dipole 312. As shown in the side view of Figure 24, the dipoles are balun fed by a balun feedline 320 coupled to a respective line 360 or 361.

The folded dipoles 303,304 are retained together by insulating clips 400 shown in detail in Figures 27-29. The dipole 304 is shown being inserted into the clip 400 in figure 27. The arm of the dipole 304 shown in figure 27 has a pair of strips 401, 402 which meet at a folded end 403 having a distal outer edge, and a proximal inner edge 404.

The clip 400 has a frame p rti n formed by c nvex uter side wall 415, concave inner side wall 414, and a pair of end walls 412. The side walls 414,415 are joined by a dividing wall 416 and a pair of lateral strips 413. Each end wall 412 is formed with a pair of tabs 417 which are bent down as shown in Figure 29. The end 403 of the folded dipole 304 is inserted into slot 410 between tab 417 and dividing wall 416 with the tab 417 folded down. The dipole 301 is then pulled back slightly so that the inner edge 404 of the folded end engages the tab 417 to lock the dipole in place.

Four circular notches 418 are provided between dividing wall 416 and side walls 414,415. The purpose of the circular notches is for tolerancing between mating parts. The circular notches help the parts mate together in case there is a burr or sharp corner to the corner of the dipole arm 304 where the pair of strips 401, 402 meet the folded end 403

For proper molded parts, it is important to keep all walls the same thickness from a point of view of shrink during cooling. Therefore the dividing wall 416 is T-shaped in cross-section and a slot (not labelled) is formed between the dividing walls and the lateral strips 413. The other reason for this design is to make the mold tool an easier, cheaper tool given the hooking function of the clip.

Although many of the embodiments show three low band dipole boxes it will be appreciated that any number of dipole boxes may be employed. Further, it will be appreciated that high band elements may be provided between the low band dipole boxes of the embodiments of figures 7,8 and 10-18, as per the embodiments of figures 6 and 9

The invention provides antennas having at least two frequency bands, and dual polarization (slant 45) performance within a compact assembly. The dipole ring or square structure provides a large inner region for accommodating secondary radiating elements of one or more second array. By accommodating secondary radiating elements within the dipole boxes, isolation may be improved. By adopting symmetrical placements of secondary radiating elements within the dipole b xes good isolation can be achieved. Th arrangement allows secondary radiating

el ments to maintain a uniform spacing whilst being located within the dipole boxes, thus reducing the effect of grating lobes.

While the present invention has been illustrated by the description of the embodiments thereof, and while the embodiments have been described in detail, it is not the intention of the Applicant to restrict or in any way limit the scope of the appended claims to such detail. Additional advantages and modifications will readily appear to those skilled in the art. Therefore, the invention in its broader aspects is not limited to the specific details, representative apparatus and method, and illustrative examples shown and described. Accordingly, departures may be made from such details without departure from the spirit or scope of the Applicant's general inventive concept.

For instance, sub-reflectors may be employed to achieve desired beam patterns. Thus, for example, each cross dipole may be framed by four conductive side walls which broaden the beam width and improve isolation.

The feed network shown is a microstrip configuration: that is, the PCB 309 is a dielectric substrate which carries conductive microstrip feedlines on its upper face shown in Figures 22 and 23, and carries a conductive ground plane (for instance a layer of copper) on its reverse side (not shown). In an alternative air-suspended microstrip configuration, the conductive microstrip is separated from the ground plane by an air gap.

The high frequency cross dipoles lie closer to the ground plane than the low frequency folded dipoles, as shown most clearly in Figures 24 and 25. However, in alternative embodiments (not shown) the height of the feed legs 305-308 may be reduced from the height shown. In extreme cases it is possible that the low frequency folded dipoles may lie closer to the ground plane than the high frequency cross dipoles. In this case, the cross dipoles will be mounted closer together to provide sufficient clearance.
The clip shown in the figures has a concave edge and a convex edge so as to fit within a ring configuration. Optionally the clip may have straight sides and perform the same function/fit for the square dipole configurations.

CLAIMS:

1. A folded dipole having a dipole axis and a pair of arms which together have a profile which is concave on one side and convex on the other when viewed along the dipole axis.

2. A folded dipole according to claim 1 wherein the arms are at least partially curved.

3. A folded dipole according to claim 2 wherein the arms have curved portions which have a substantially constant radius of curvature.

4. A folded dipole according to claim 2 wherein the arms are at least partially curved in a plane substantially orthogonal to the dipole axis.

5. A folded dipole according to claim 1 wherein the pair of arms meet at a corner.

6. A folded dipole according to claim 5 wherein the corner subtends an angle lying in the range of 80° to 100°.

7. A folded dipole according to claim 5 wherein each arm is substantially straight.

8. A folded dipole according to claim 5 wherein the corner is truncated.

9. A folded dipole according to claim 1 further comprising a feed line coupled to a concave side of the pair of arms.

10. A folded dipole according to claim 1 wherein the pair of arms are formed of sheet material.

11. A folded dipole according to claim 10 wherein both arms are formed from the same sheet.

12.A folded dipole according to claim 1 further comprising a first feedline coupled to one of the arms and a second feedline coupled to the other arm.

13.An antenna comprising a ground plane; and a folded dipole according to claim 1 arranged with its dipole axis directed away from the ground plane.

14.A cellular base station including an antenna according to claim 13.

15.A communication system including a network of cellular base stations according to claim 14.

16.A dipole box comprising two or more folded dipoles arranged around a central region, each folded dipole having a dipole axis and a pair of arms which together have a profile which is concave on one side and convex on the other when viewed along the dipole axis.

17.A dipole box according to claim 16 wherein each pair of arms has a curved portion with a centre of curvature which is located in the central region.

18.A dipole box according to claim 16 comprising four or more folded dipoles arranged around the central region, each folded dipole having a dipole axis and a pair of arms which together have a profile which is concave on one side and convex on the other when viewed along the dipole axis.

19.A dipole box according to claim 18 wherein the dipoles are arranged as orthogonally opposed pairs.

20.A dipole box according to claim 19 wherein each pair of dipoles is oriented at about $\pm 45°$ with respect to vertical.

21.An antenna comprising a ground plane; and a dipole box according to claim 16 arranged with the dipole axes directed away from the ground plane.

22.An antenna according to claim 21 comprising two or more dipole boxes spaced apart along an antenna axis, each dipole box comprising four dipoles oriented at about $\pm 45°$ with respect to the antenna axis.

23.An antenna according to claim 21 wherein the dipole boxes are operable over a low frequency range, and the antenna further comprises one or more columns of high frequency radiating elements superimposed with the dipole boxes and operable over a high frequency range having a mid point higher than a mid point of the low frequency range.

24.An antenna according to claim 23 wherein the high frequency radiating elements are cross dipoles.

25.An antenna according to claim 21 comprising two or more dipole boxes arranged along an antenna axis, each dipole box comprising a pair of substantially semicircular folded dipoles.

26.A cellular base station including an antenna according to claim 21.

27.A communication system including a network of cellular base stations according to claim 26.

28.An electrically insulating retaining element for retaining together adjacent ends of a pair of dipoles, the element comprising a frame formed by an opposed pair of side walls and an opposed pair of end walls; a dividing wall joining the opposed pair of side walls; and a pair of projections each provided on a respective end wall and directed inwardly towards the dividing wall.

29.An element according to claim 28 wherein the projections are folded tabs.

30.An element according to claim 28 wherein the opposed pair of side walls includes a convex outer wall and a concave inner wall.

31.A dipole assembly comprising two or more dipoles having adjacent nds retained together by electrically insulating retaining elements.

32.An assembly according to claim 31 wherein the dipoles are arranged end to end so as to enclose a central region.

33.An assembly according to claim 31 wherein the dipoles are folded dipoles, and wherein the adjacent ends have proximal inner edges which are engaged by the retaining element(s) to secure the dipoles in place.

34.An assembly according to claim 31 wherein the retaining element(s) comprise(s) a frame formed by an opposed pair of side walls and an opposed pair of end walls; a dividing wall joining the opposed pair of side walls; and a pair of projections each provided on a respective end wall and directed inwardly towards the dividing wall.

35.An assembly according to claim 34 wherein the dipoles are folded dipoles, and wherein the adjacent ends have proximal inner edges which are each engaged by a respective projection to secure the dipoles in place.

36.An antenna comprising a ground plane; and a dipole assembly according to claim 31.

37.A cellular base station including an antenna according to claim 36.

38.A communication system including a network of cellular base stations according to claim 37.

39.An antenna comprising:

a first module comprising an outer box of two or more dipoles arranged around a first central region, and an inner box of two or more dipoles located in the first central region concentrically with the outer box; and

a second module comprising an outer box of two or more dipoles arrang d around a second c ntral region which is spaced from the first region,

and an inner box f two or more dipoles located in the second central region concentrically with the outer box.

40. An antenna according to claim 39 wherein each inner box is operable over a high frequency range and each outer box is operable over a low frequency range having a mid point lower than a mid point of the high frequency range.

41. An antenna according to claim 39 further comprising an additional high frequency dipole box operable in the high frequency range and positioned in a gap between the first and second modules whereby the spacing between the high frequency boxes is smaller than the spacing between the low frequency boxes.

42. An antenna according to claim 39 further comprising a ground plane.

43. An antenna according to claim 39 wherein the outer box dipoles comprise folded dipoles.

44. An antenna according to claim 39 wherein the inner box dipoles comprise folded dipoles.

45. An antenna according to claim 39 wherein the outer box dipoles each have a dipole axis and a pair of arms which together have a profile which is concave on one side and convex on the other when viewed along the dipole axis

46. An antenna according to claim 39 wherein the inner box dipoles comprise folded dipoles having a dipole axis and a pair of arms which together have a profile which is concave on one side and convex on the other when viewed along the dipole axis.

47. An antenna according to claim 39 wherein the outer box dipoles are arranged in a linear array.

48. An antenna according to claim 39 wherein each outer box comprises orthogonally opposing pairs of dipoles.

49. An antenna according to claim 39 wherein each inner box comprises orthogonally opposing pairs of dipoles.

50. An antenna according to claim 48 wherein each pair of dipoles in the outer box is off-set with respect to vertical by about ± 45°.

51. An antenna according to claim 48 wherein each pair of dipoles in the inner box is off-set with respect to vertical by about ± 45°.

52. An antenna according to claim 39 wherein the outer box dipoles comprise two orthogonally opposed pairs of folded dipoles off-set with respect to vertical by about ± 45° which each have a dipole axis and a pair of arms which together have a profile which is concave on one side and convex on the other when viewed along the dipole axis; and the inner box dipoles comprise two orthogonally opposed pairs of folded dipoles off-set with respect to vertical by about ± 45° having a dipole axis and a pair of arms which together have a profile which is concave on one side and convex on the other when viewed along the dipole axis.

53. An antenna according to claim 52 wherein the arms of the inner and outer box dipoles are curved.

54. An antenna according to claim 52 wherein the arms of the inner and outer box dipoles are straight.

55. An antenna according to claim 52 wherein the arms of the outer box dipoles are curved and the arms of the inner box dipoles are straight.

56. An antenna according to claim 52 wherein the arms of the outer box dipoles are straight and the arms of the inner box dipoles are curved.

57. An antenna according to claim 39 wherein the outer box dipoles comprise two orthogonally opposed pairs of folded dipoles off-set with respect to vertical by about ± 45° which each have a dipole axis and a pair of arms which t geth r have a profile which is c ncave on one side and convex on the other wh n vi wed along the dipole axis; and the inner box dipoles comprise two orthogonally opposed pairs of folded dipoles off-set with respect to vertical by

about ± 45° in a diamond-shaped configuration.

58. An antenna according to claim 57 wherein the arms of the outer box dipoles are curved.

59. An antenna according to claim 57 wherein the arms of the outer box dipoles are straight.

60. An antenna according to claim 39 wherein the outer box dipoles comprise two orthogonally opposed pairs of folded dipoles off-set with respect to vertical by about ± 45° in a diamond-shaped configuration; and the inner box dipoles comprise two orthogonally opposed pairs of folded dipoles off-set with respect to vertical by about ± 45° which each have a dipole axis and a pair of arms which together have a profile which is concave on one side and convex on the other when viewed along the dipole axis.

61. An antenna according to claim 60 wherein the arms of the inner box dipoles are curved.

62. An antenna according to claim 60 wherein the arms of the inner box dipoles are straight.

63. A cellular base station including an antenna according to claim 39.

64. A communication system including a network of cellular base stations according to claim 63.

65. A method of manufacturing a folded dipole having a dipole axis and a pair of arms which together have a profile which is concave on one side and convex on the other when viewed along the dipole axis, the method comprising forming the pair of arms from a sheet of conductive material.

66. A method according to claim 65 wherein the arms are formed by stamping the arms out from the she t.

67. A method according to claim 65 further comprising forming one or more feed legs from the sheet.

68.A method according to claim 67 further comprising bending the feed leg(s) out of the plane of the sheet.

Abstract

IMPROVEMENTS RELATING TO DIPOLE ANTENNAS

The invention relates in part to a folded dipole having a dipole axis and a pair of arms (8,9) which together have a profile which is concave on one side and convex on the other when viewed along the dipole axis. The dipoles may be arranged as a dipole box around a central region, typically in a generally circular or square configuration. Further elements (23,28) may be placed in the dipole box or in the gaps between dipole boxes. The antenna may be a single-band antenna, or a multi-band antenna with the further elements operating in a different frequency band to the dipole boxes. The further elements may be concentric dipole boxes. The invention is particularly suited for use in a cellular base station panel antenna.

CSPEC20090

7836/88994

DECLARATION AND POWER OF ATTORNEY

As a below named inventor, I hereby declare:

That my residence, post office address and citizenship are as stated below next to my name.

That I verily believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural inventors are named below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

IMPROVEMENTS RELATING TO DIPOLE ANTENNAS

the specification of which (check one)
(X) is attached hereto.
( ) was filed on ______________________ as
Application Serial No. ____________________
and was amended on ____________________
(if applicable)

That I have reviewed and understand the contents of the above-identified specification, including the claim, as amended by any amendment referred to above.

That I acknowledge the duty to disclose information known to be material to patentability of this application in accordance with Title 37, Code of Federal Regulations, §1.56(a).

That I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate on this invention having a filing date before that of the application on which priority is claimed:

Prior Foreign Application(s)

			Priority Claimed	
________ (Number)	________ (Country)	________ (Day/Month/Year Filed)	☐ Yes	☐ No
________ (Number)	________ (Country)	________ (Day/Month/Year Filed)	☐ Yes	☐ No

I hereby claim the benefit under 35 U.S.C. § 119(e) of any United States provisional application(s) listed below.

________ (Application Number)	________ (Filing Date)
________ (Application Number)	________ (Filing Date)

That I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

United States Application(s)

(Application Serial No.)	(Filing Date)	(Status)-(Patented, pending, abandoned)
(Application Serial No.)	(Filing Date)	(Status)-(Patented, pending, abandoned)

That all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Cod and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

I hereby appoint the following attorneys, with full power of substitution and revocation, to prosecute this application and to transact all business in the United States Patent and Trademark Office connected therewith and request that all correspondence and telephone calls in respect to this application be directed to WELSH & KATZ, LTD., 120 South Riverside Plaza, 22nd Floor, Chicago, Illinois 60606, Telephone No. (312) 655-1500:

Attorney	Registration No.
A. Sidney Katz	24,003
Richard L. Wood	22,839
Jerold B. Schnayer	28,903
Eric C. Cohen	27,429
Joseph R. Marcus	25,060
Gerald S. Schur	22,053
Gerald T. Shekleton	27,466
James A. Scheer	29,434
Daniel R. Cherry	29,054
Edward P. Gamson	29,381
Kathleen A. Rheintgen	34,044
Thomas W. Tolpin	27,600
Jon P. Christensen	34,137
Eric D. Cohen	38,110
Walter J. Kawula, Jr.	39,724
Philip D. Segrest, Jr.	39,021
Mitchell J. Weinstein	37,963
Leonard Friedman	37,135
Steven E. Feldman	40,604
Jeffrey W. Salmon	37,435

Full name of sole or one joint inventor: Peter John Bisiules

Inventor's signature: ______________________

Date: ______________________

Residence and Post Office Address: 1427 Blanchan
LaGrange Park, Illinois 60526

Citizenship: U.S.A

Full name of sole or one joint inventor:	John H. Coult
Inventor's signature:	
Date:	
Residence and Post Office Address:	1129 W. Wellington, Suite 100 Chicago, Illinois 60657
Citizenship:	U.S.A
Full name of sole or one joint inventor:	Chin Shun-Yang
Inventor's signature:	
Date:	
Residence and Post Office Address:	5 S 270 Glenoban Drive Naperville, Illinois 60563
Citizenship:	U.S.A
Full name of sole or one joint inventor:	Joselito de la Cruz Gavilan
Inventor's signature:	
Date:	
Residence and Post Office Address:	1532 Parkside Drive Bolingbrook, Illinois 60490
Citizenship:	U.S.A
Address for Correspondence:	Eric D. Cohen WELSH & KATZ, LTD. 120 South Riverside Plaza 22nd Floor Chicago, Illinois 60606

Title: IMPROVEMENTS RELATING TO DIPOLE ANTENNAS
Applicant: Peter John Bisiules, et al.
Filed: December 13, 2002

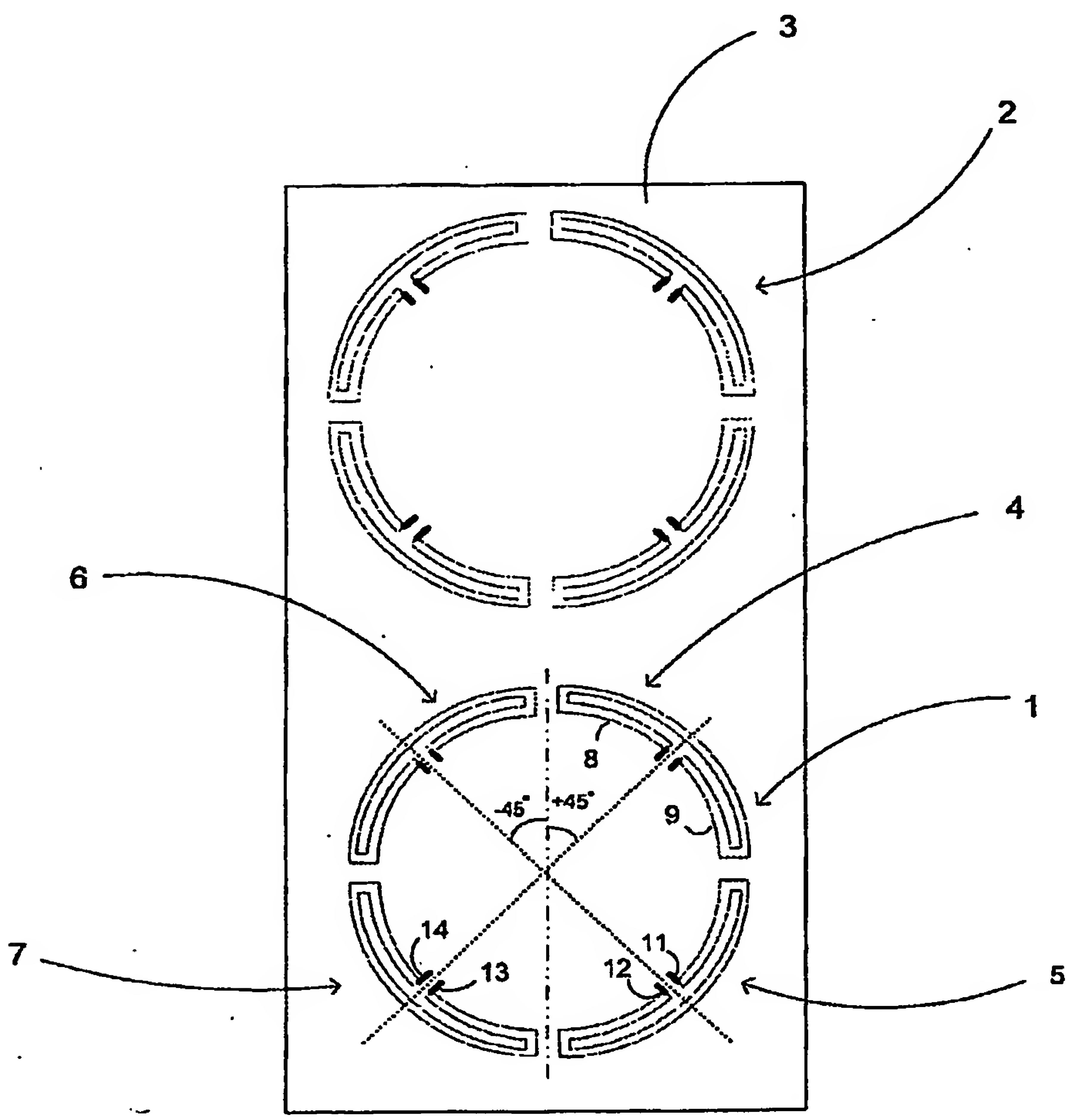


FIGURE 1

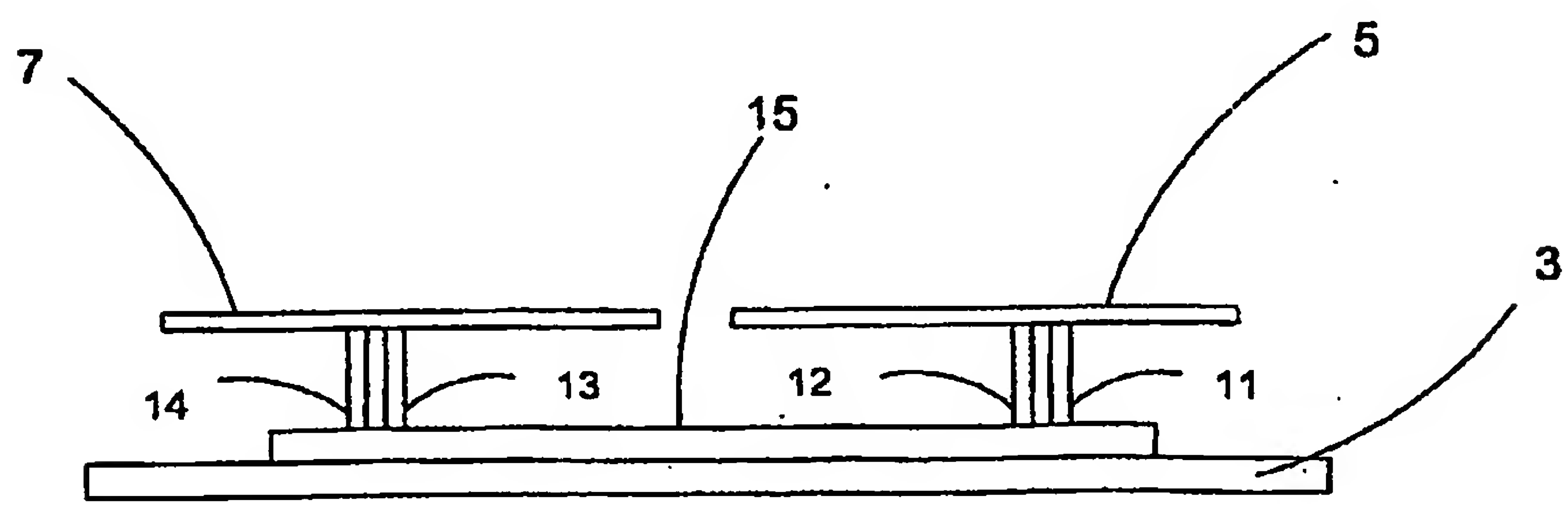


FIGURE 2

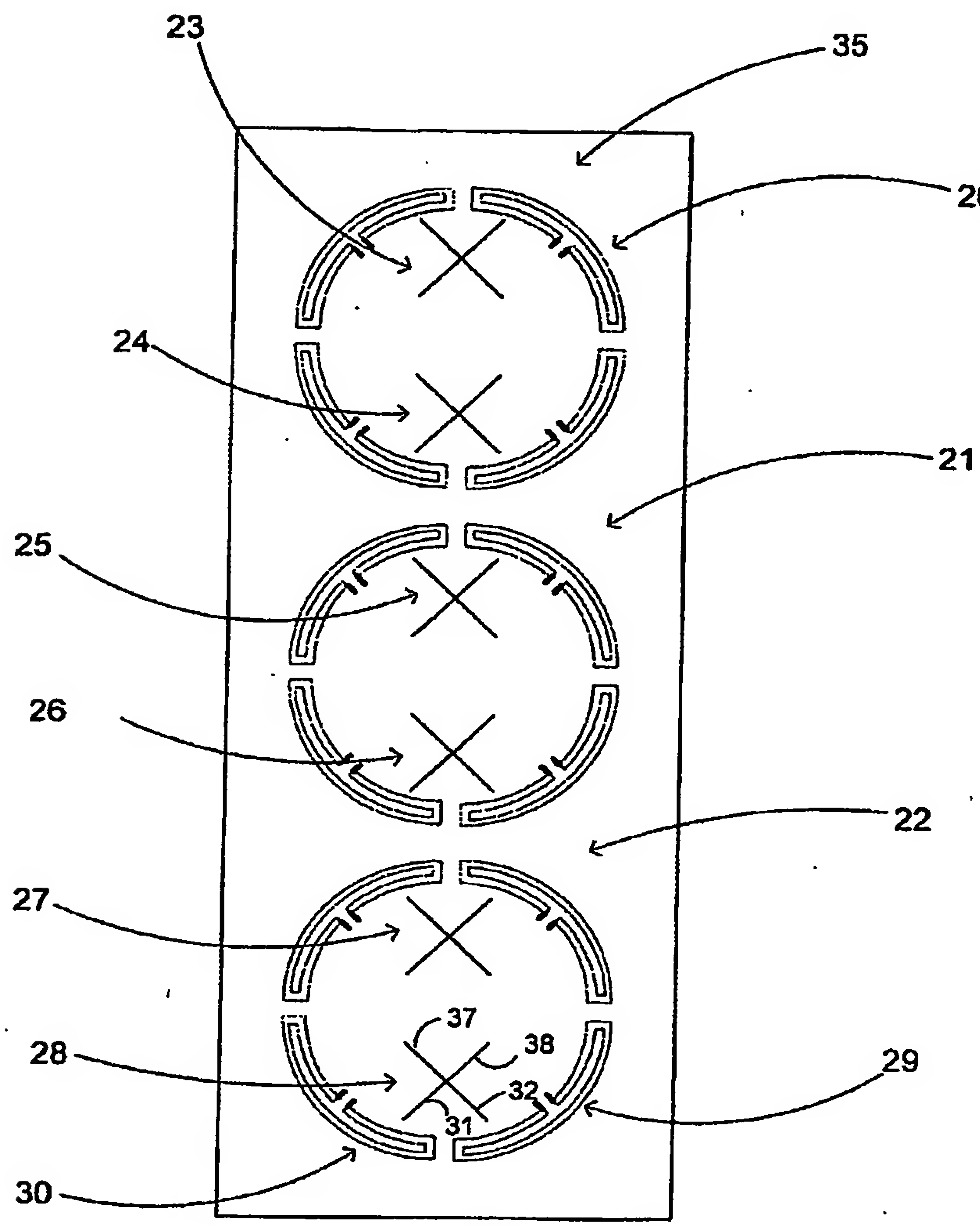


FIGURE 3

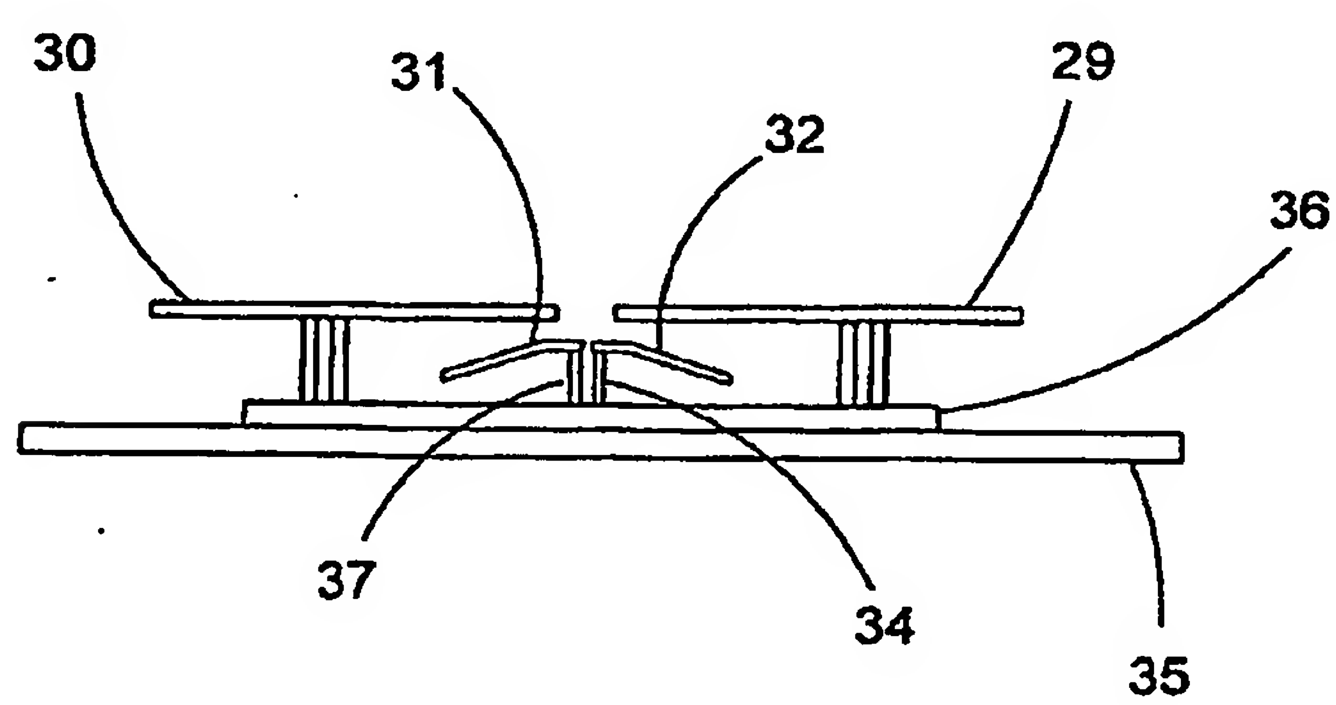


FIGURE 4

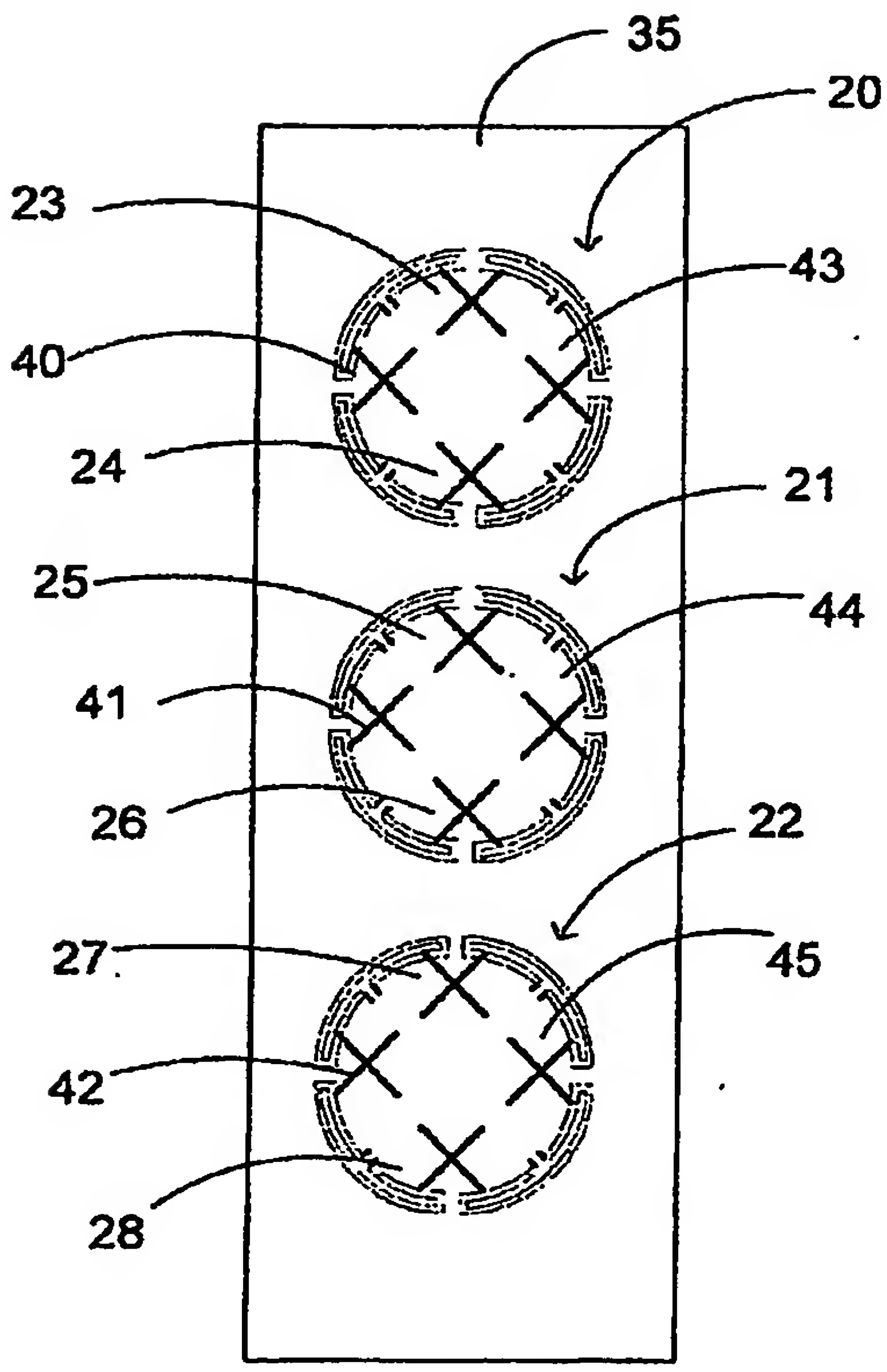


FIGURE 5

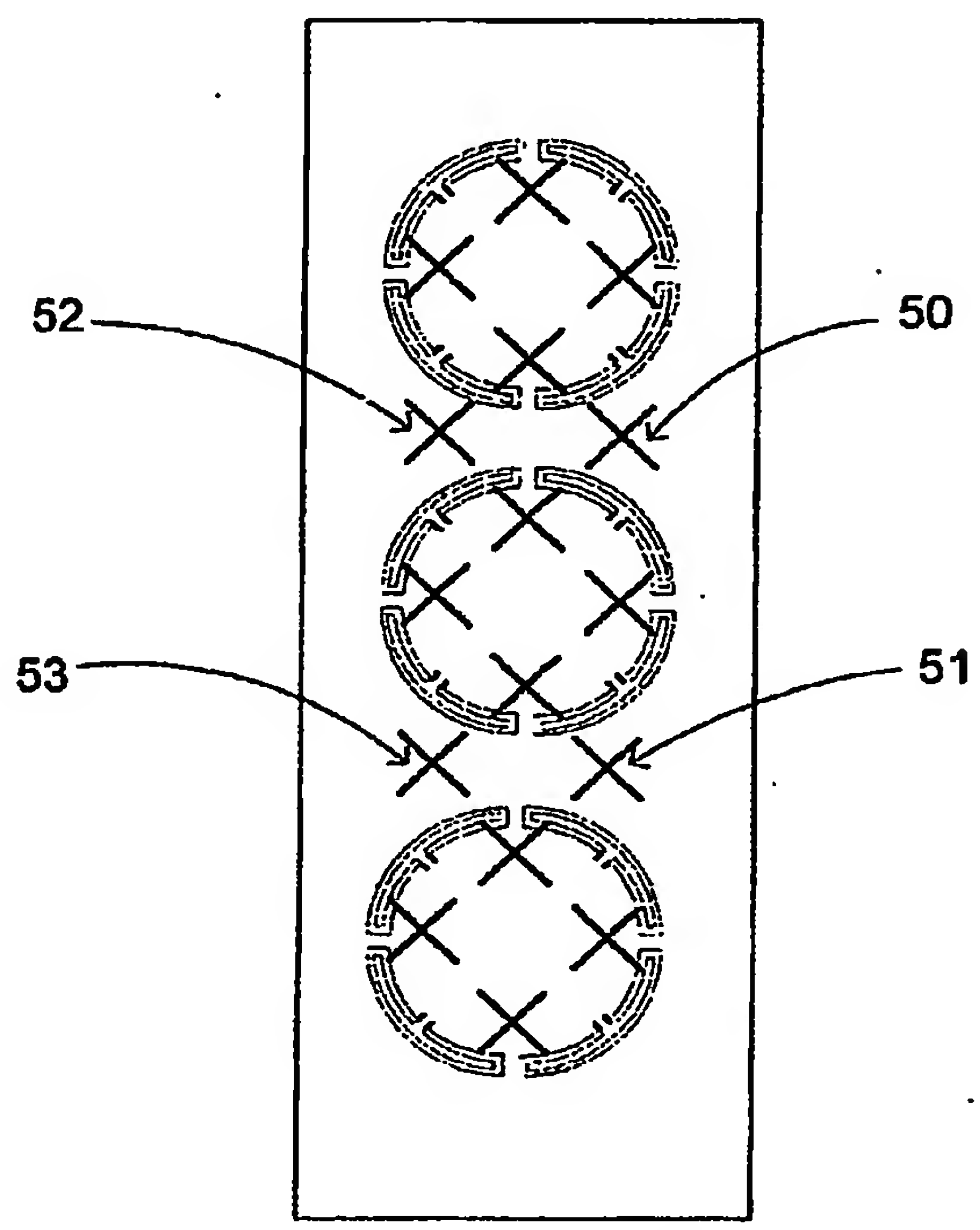


FIGURE 6

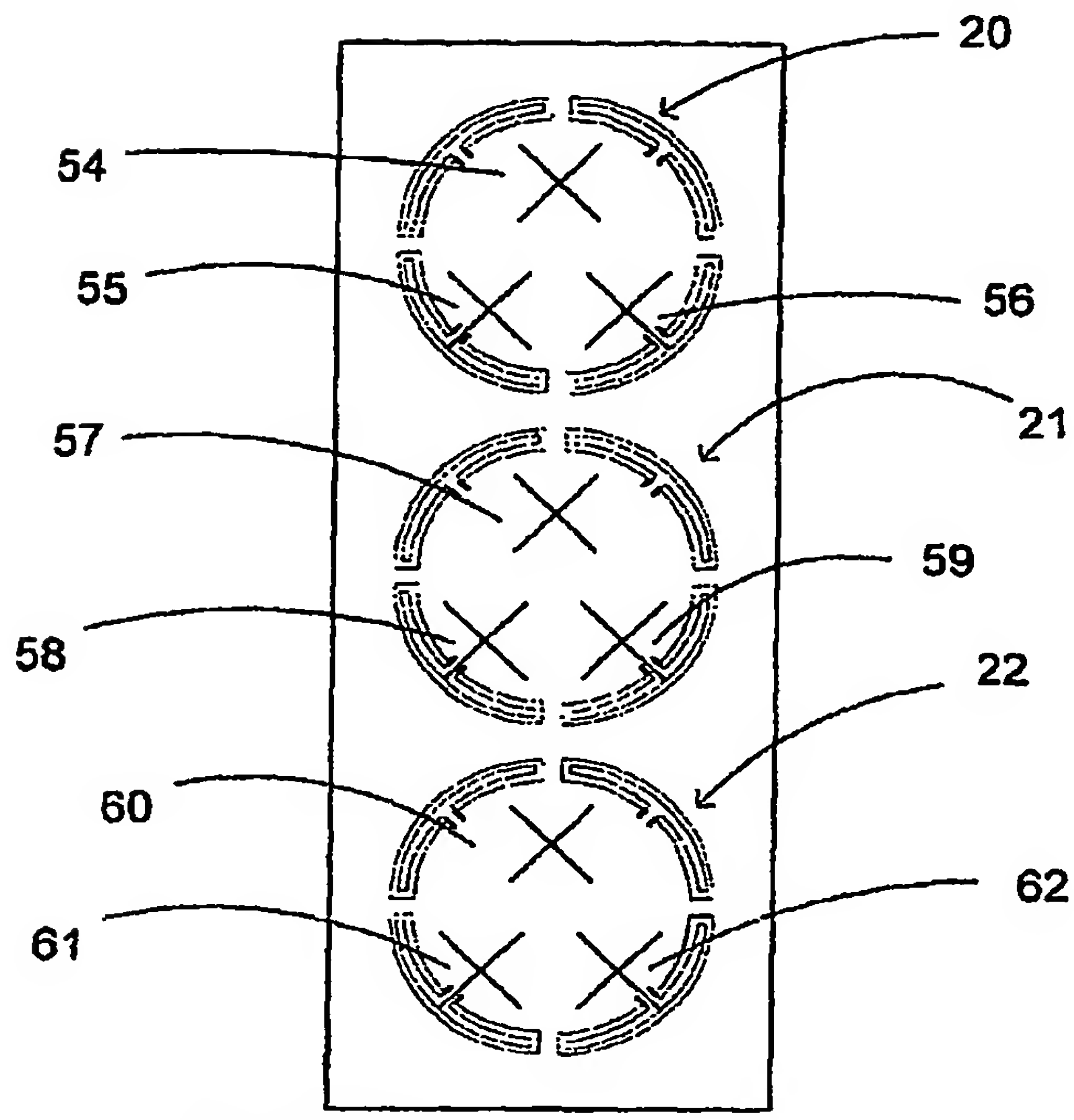


FIGURE 7

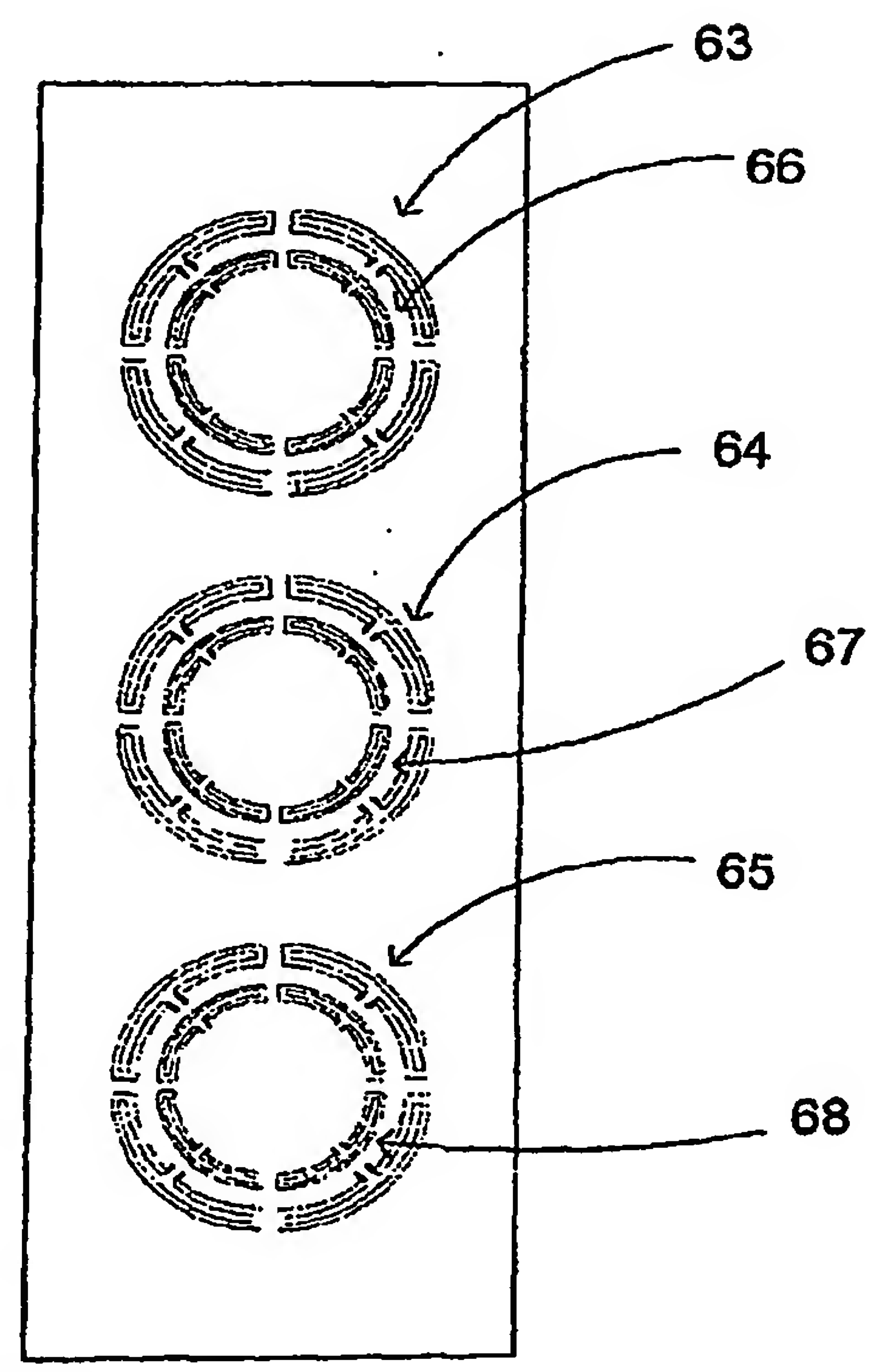


FIGURE 8

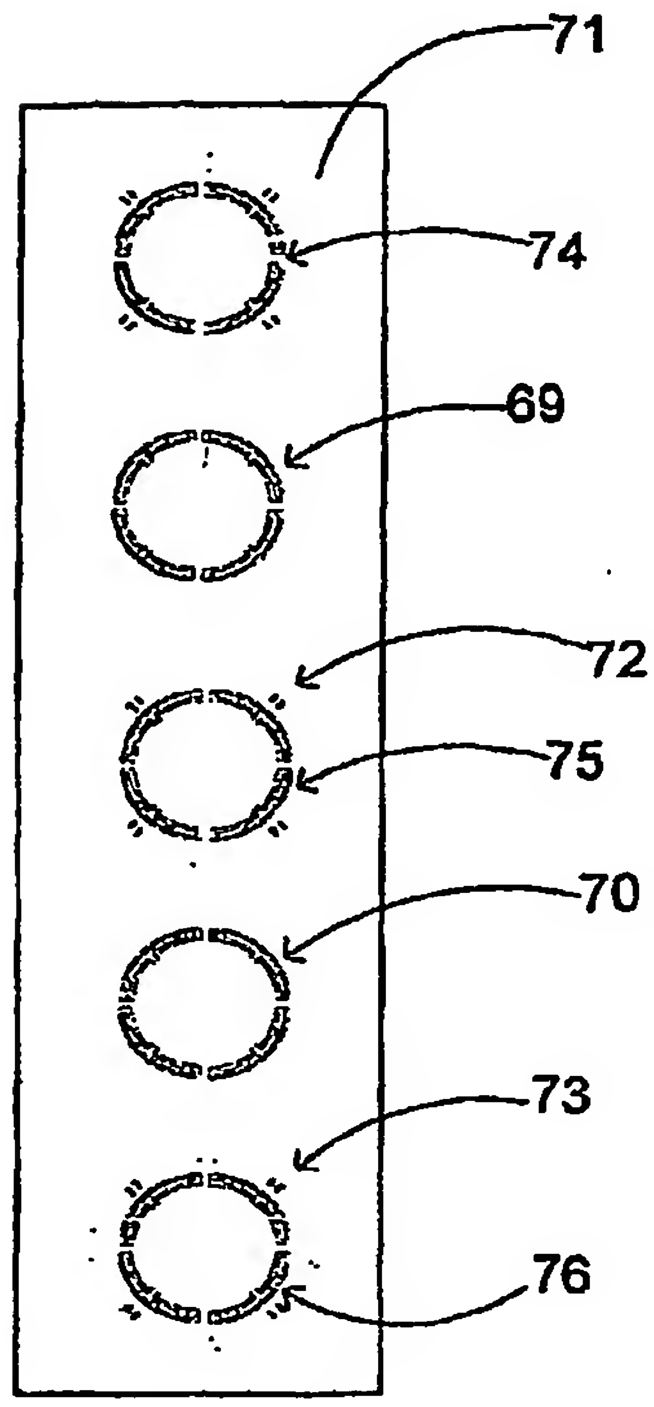


FIGURE 9

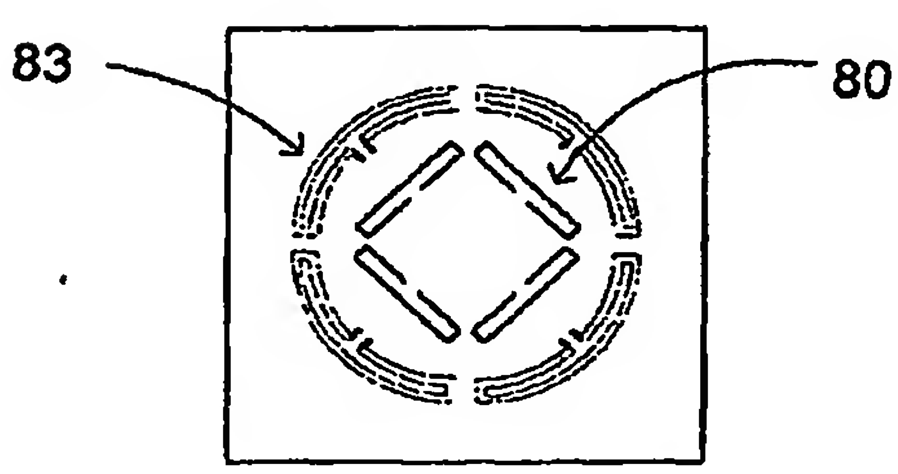


FIGURE 10

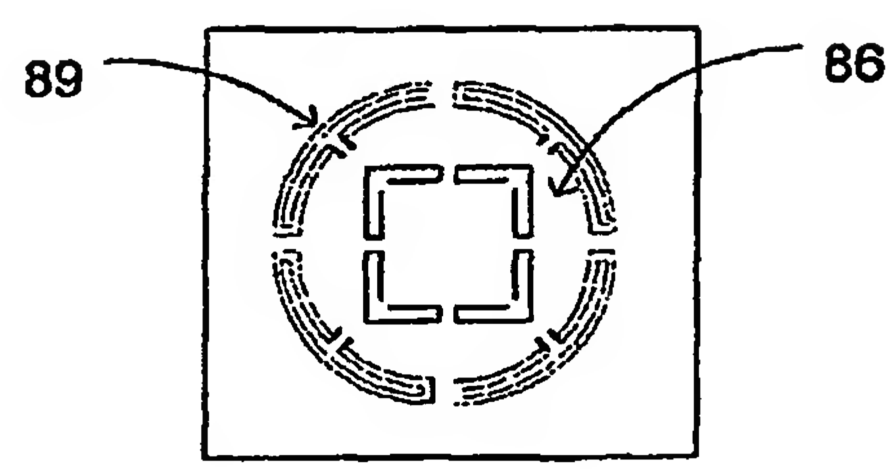


FIGURE 11

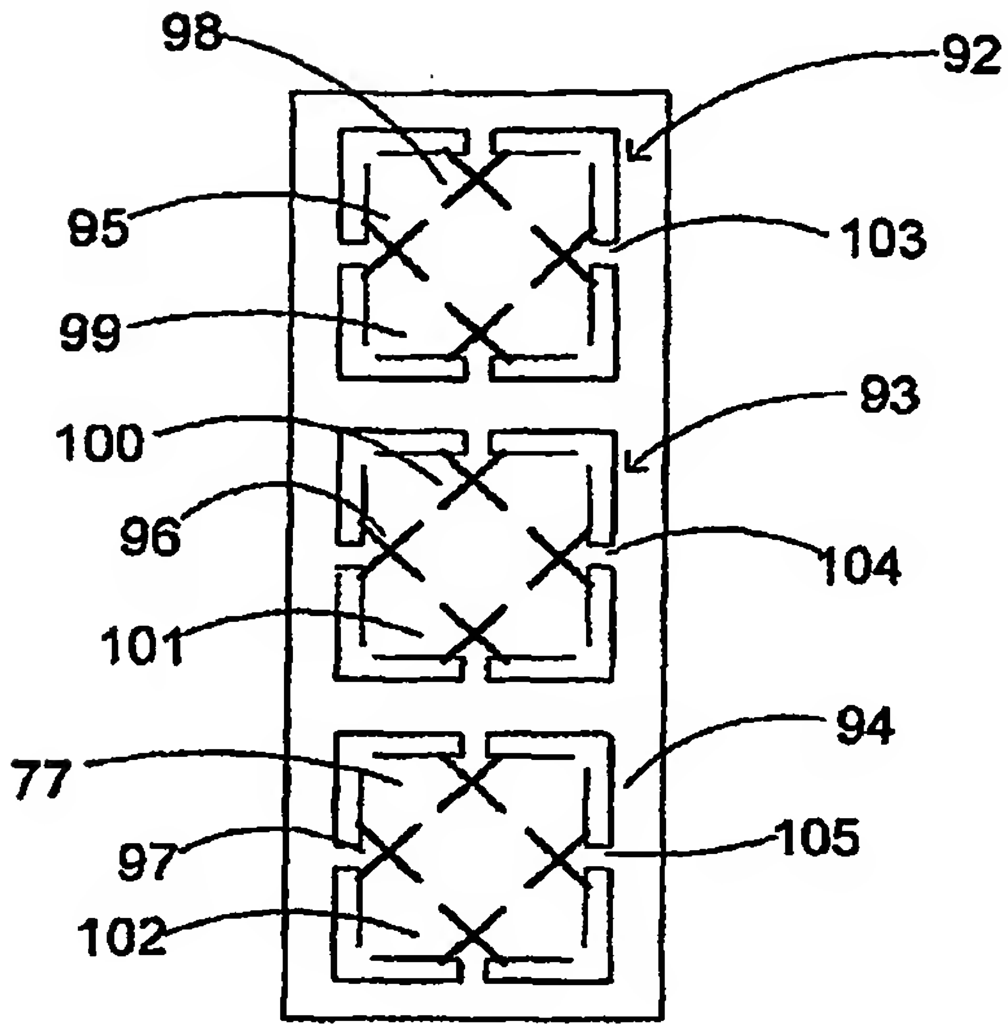


FIGURE 12

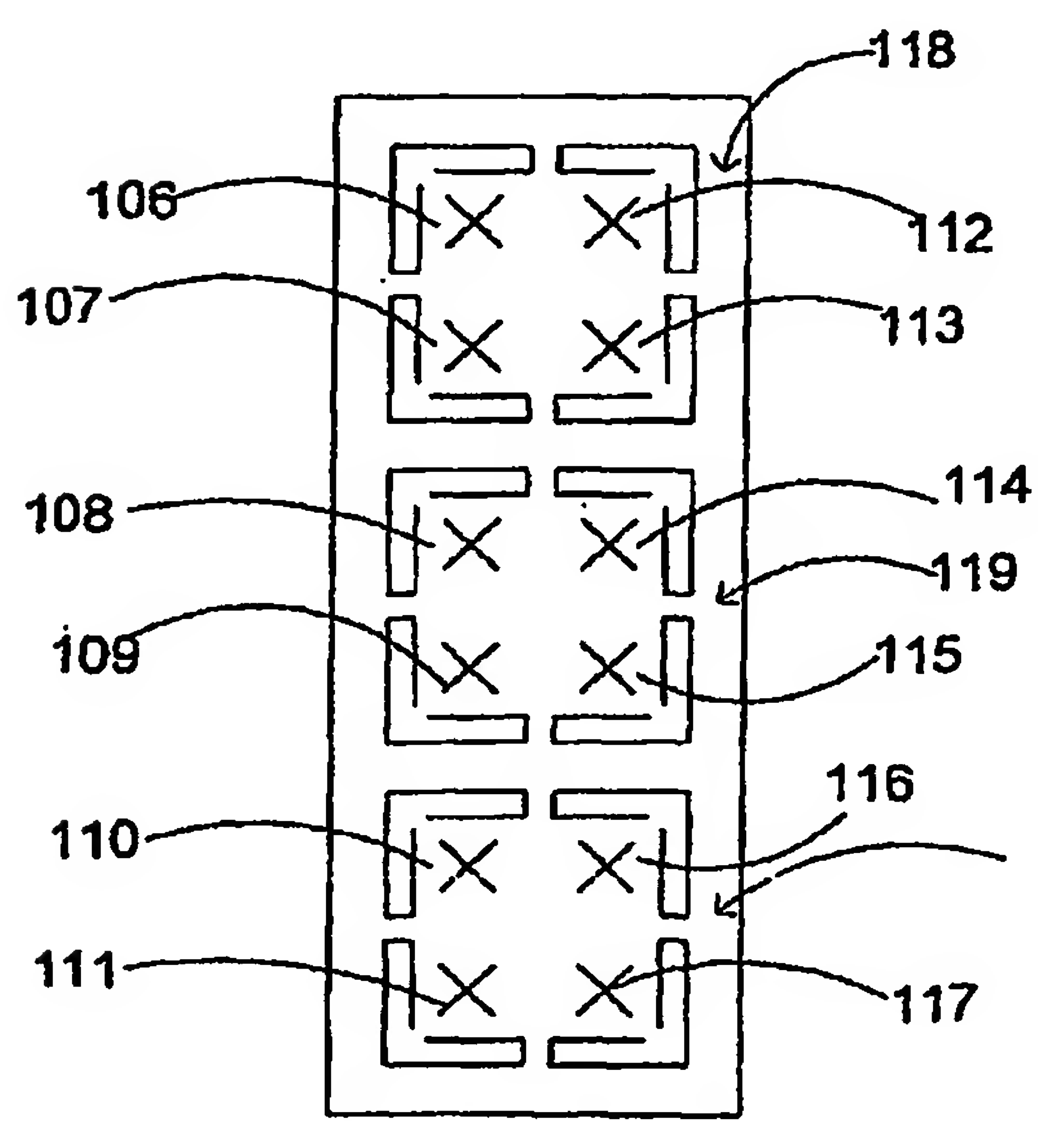


FIGURE 13

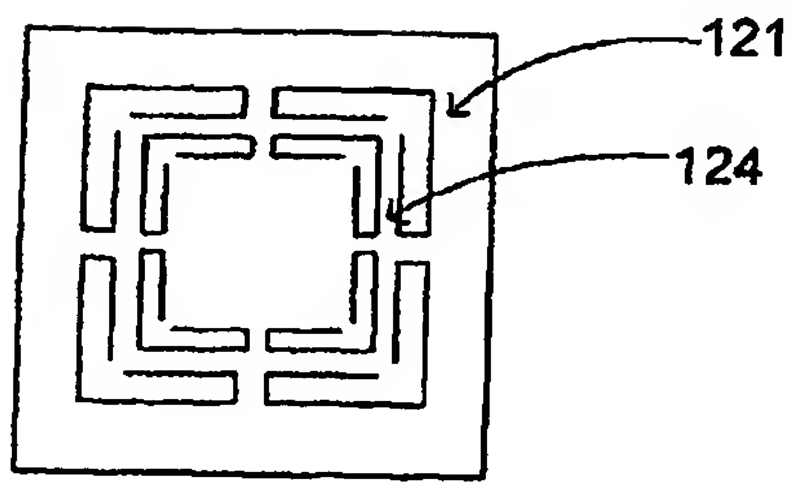


FIGURE 14

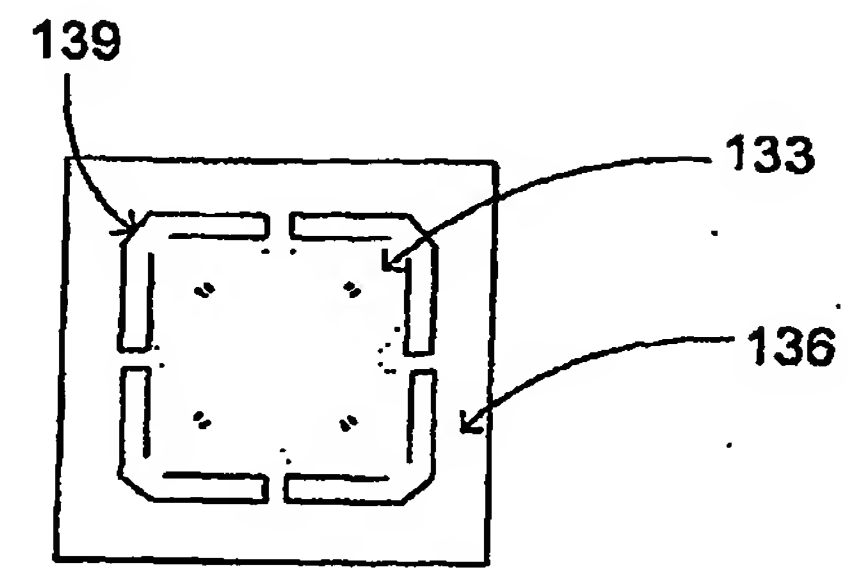


FIGURE 16

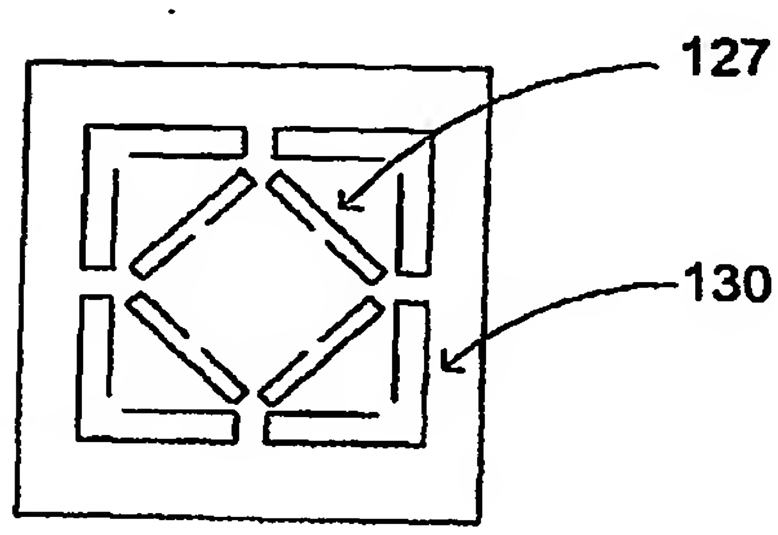


FIGURE 15

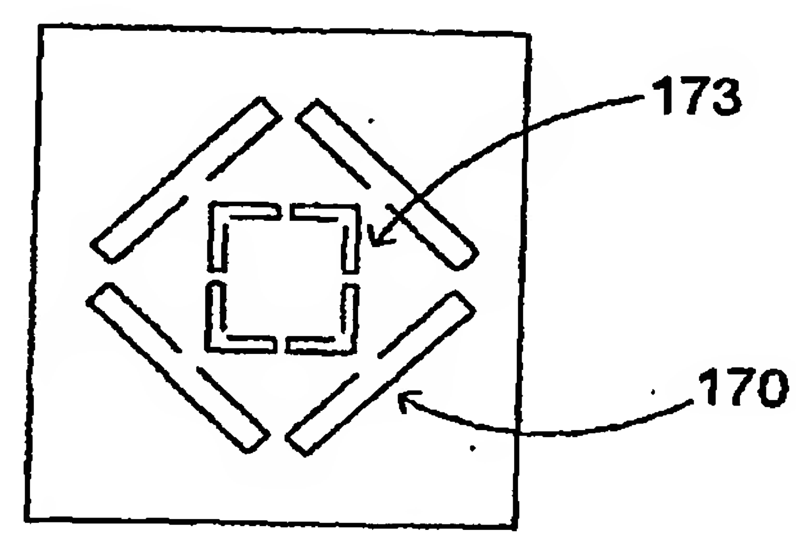


FIGURE 17

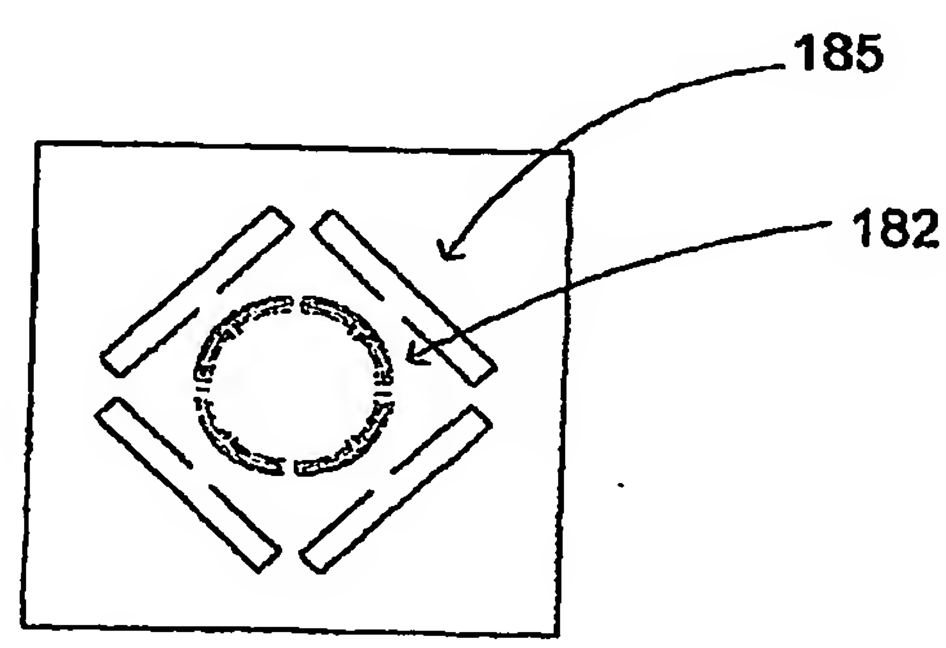


FIGURE 18

Figure 19

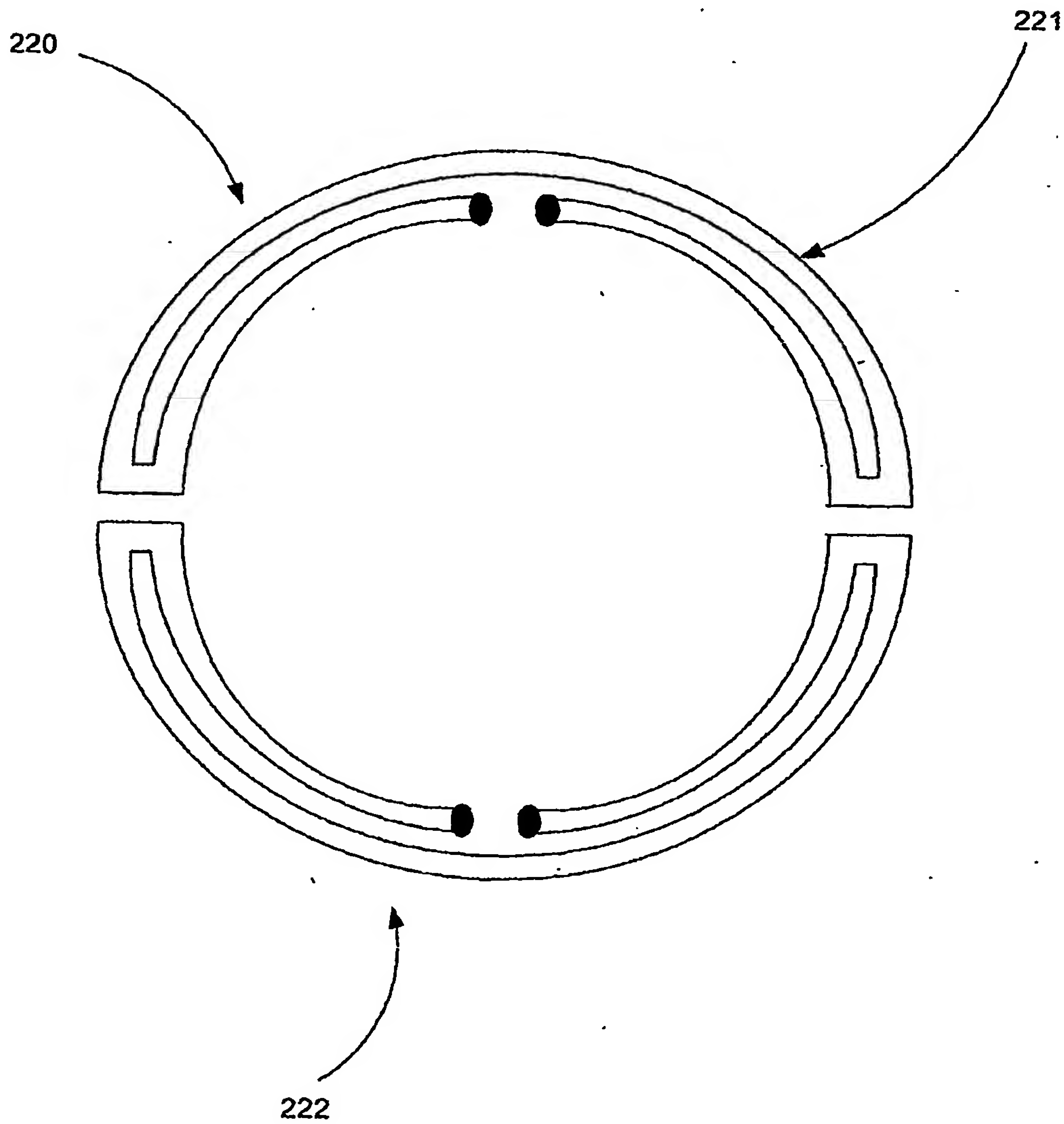


Figure 20

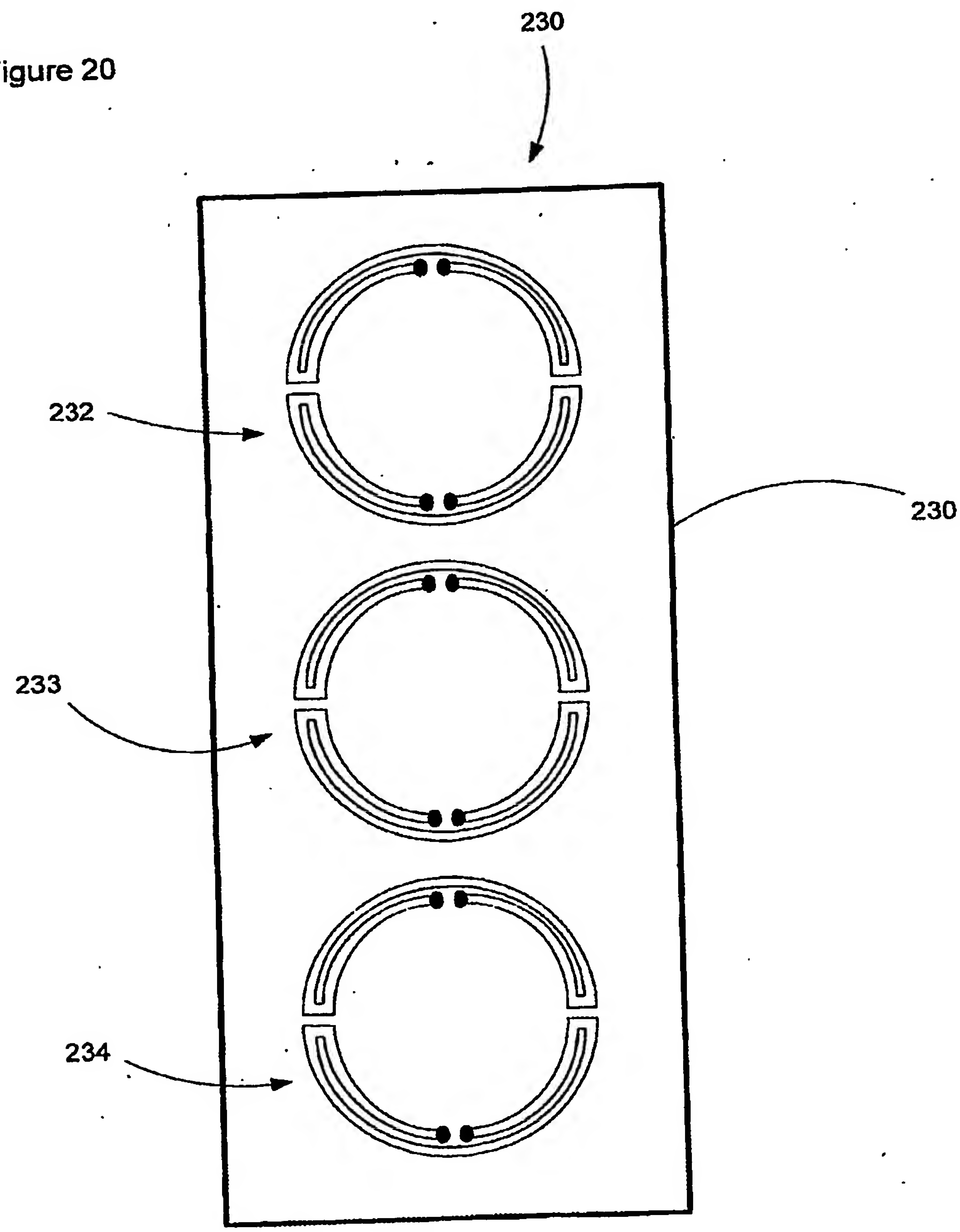
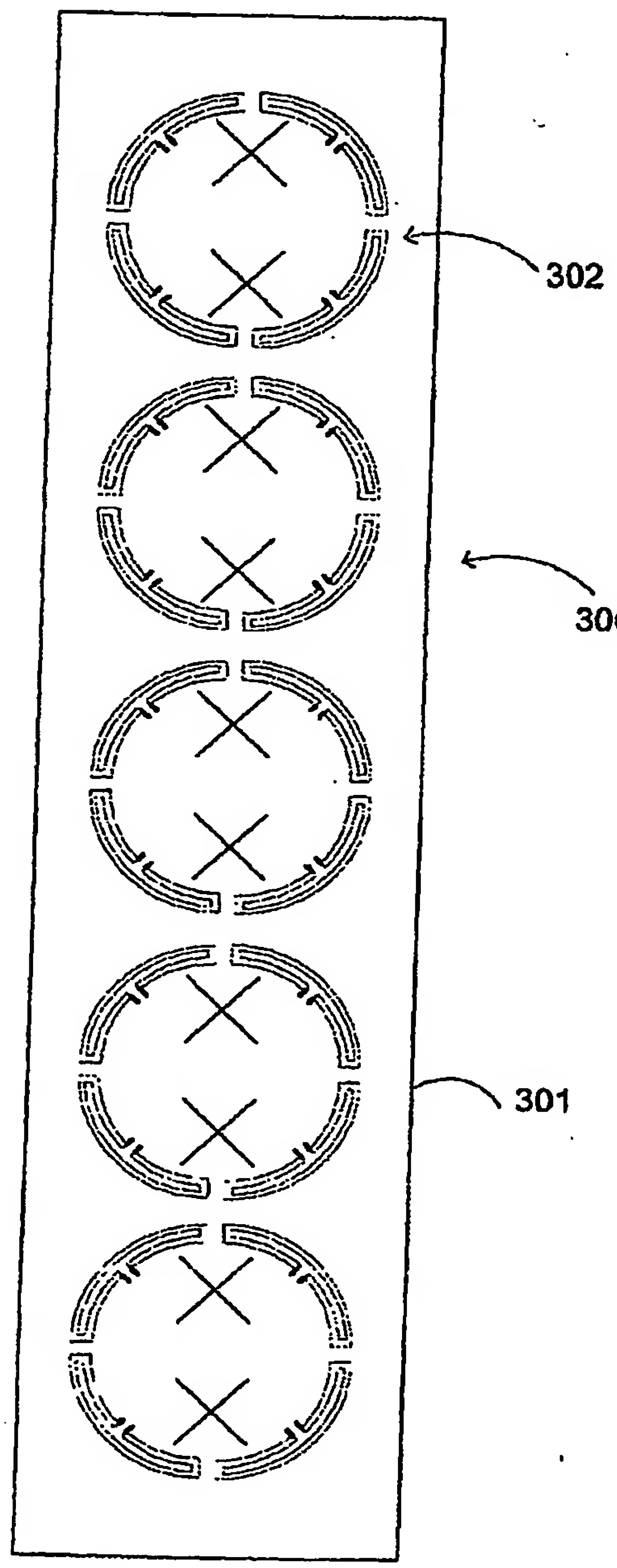


Figure 21



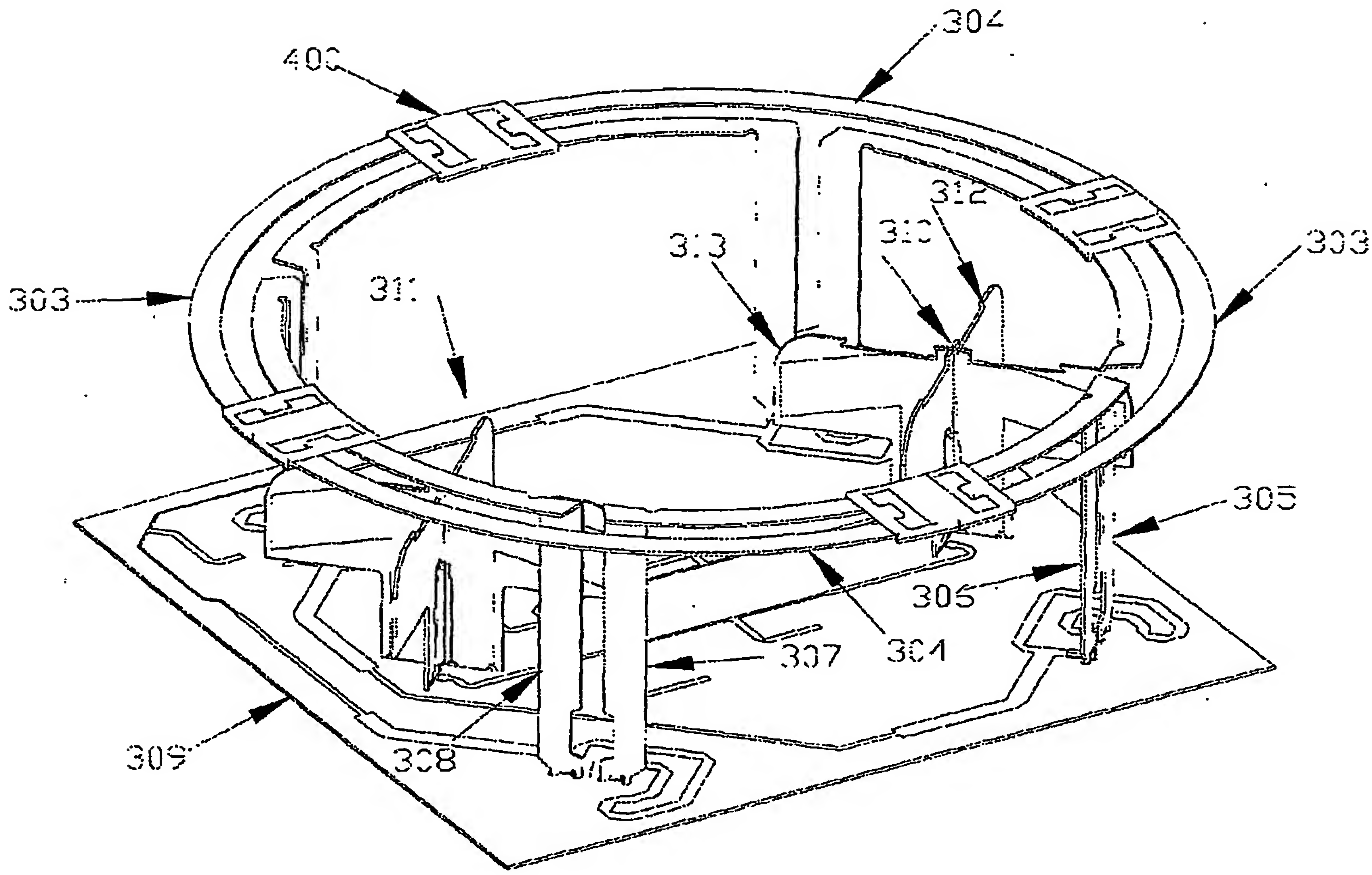


Figure 22

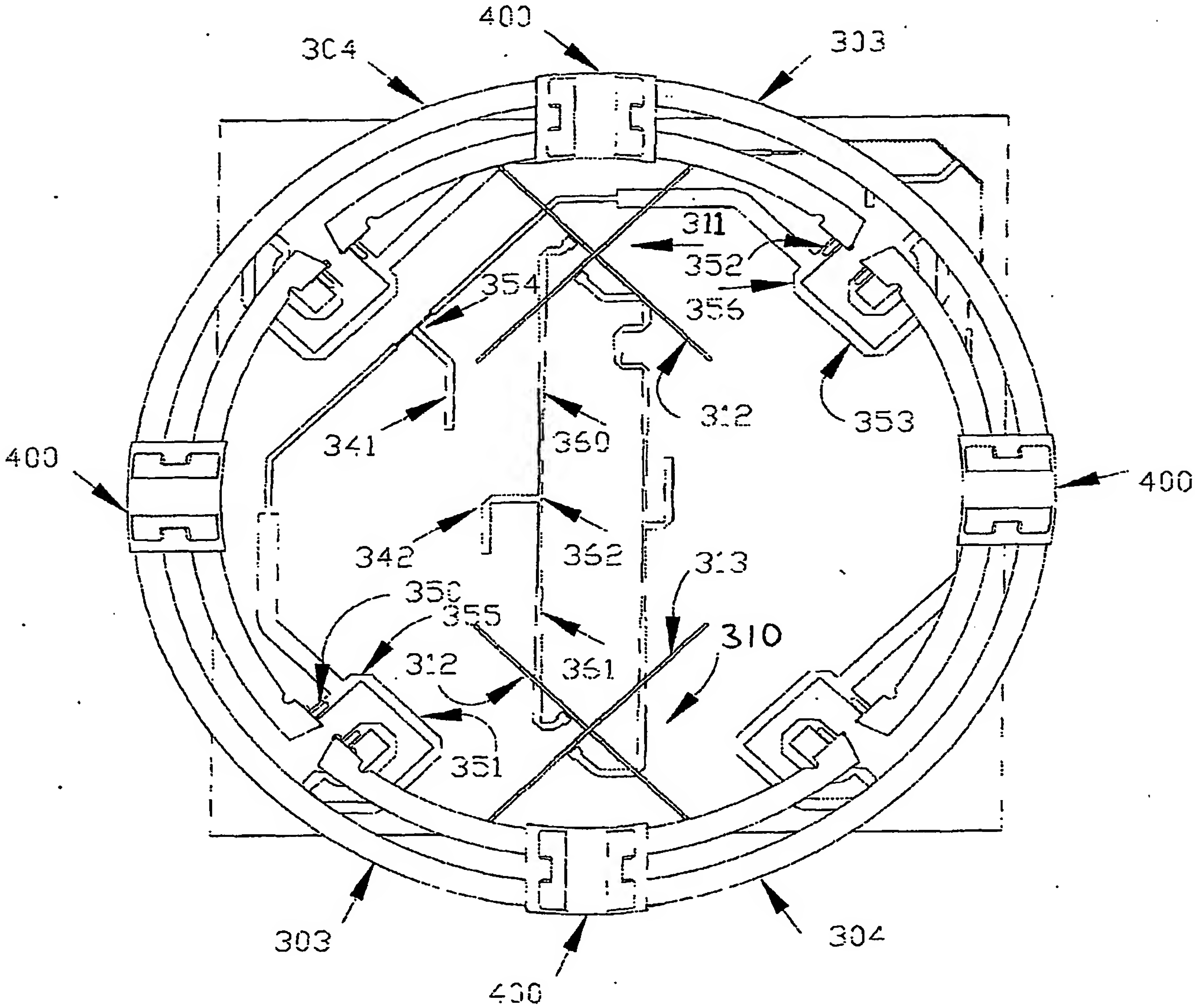

400
304
303
311
352
354
356
312
353
341
360
400
400
342
362
313
350
355
310
312
361
351
303
304
400

Figure 23

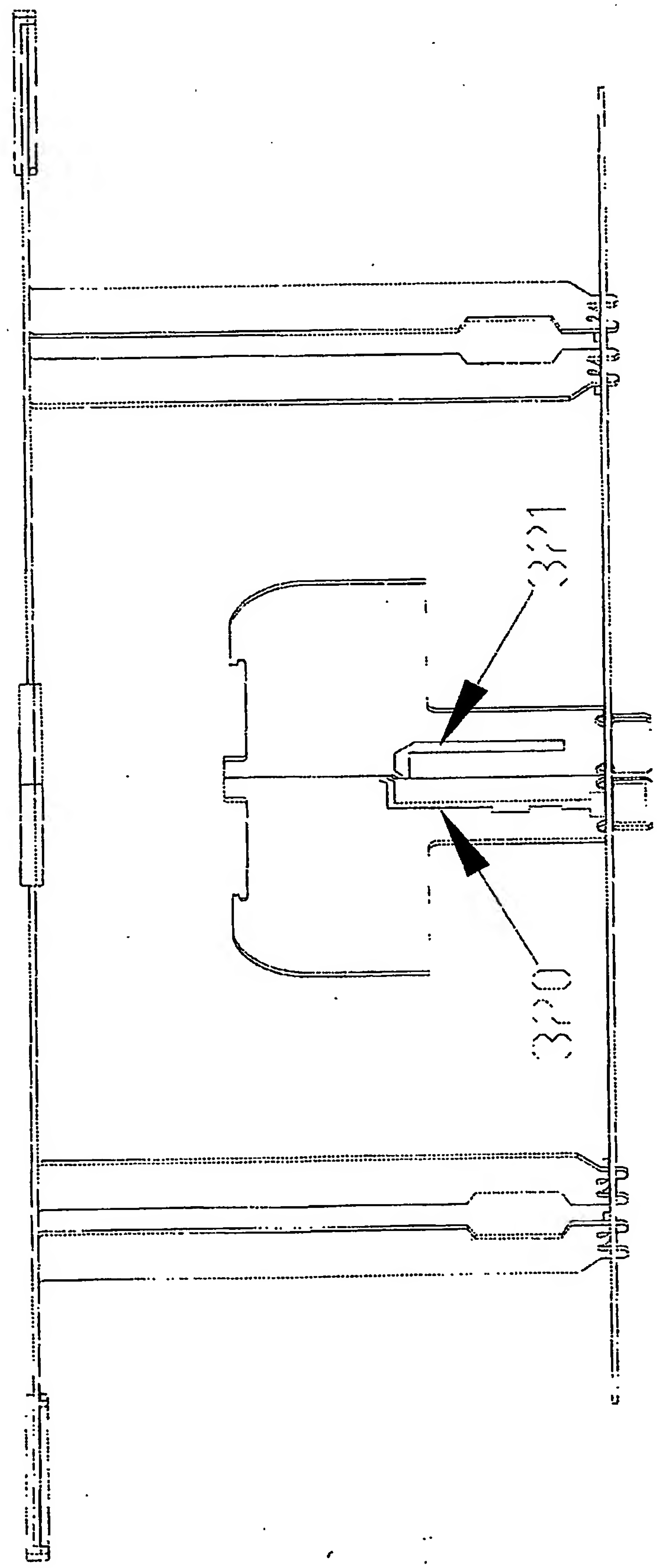


Figure 24

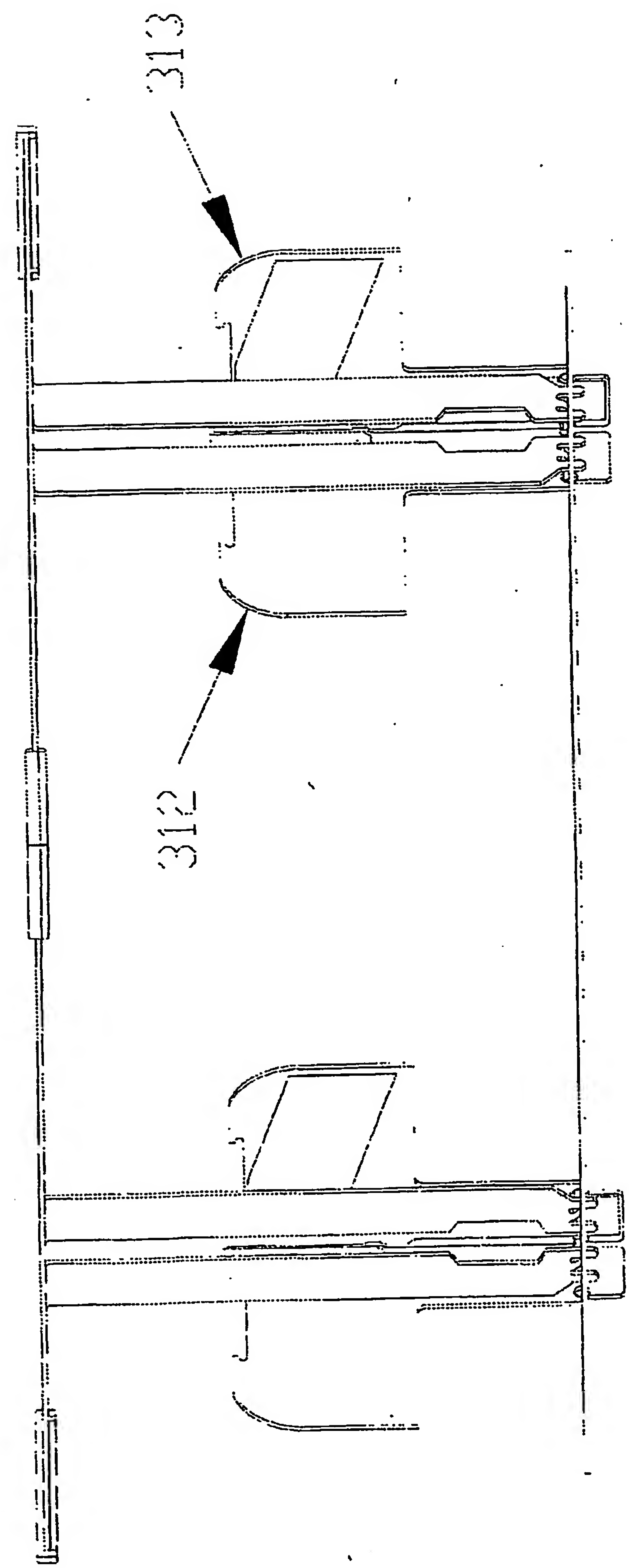
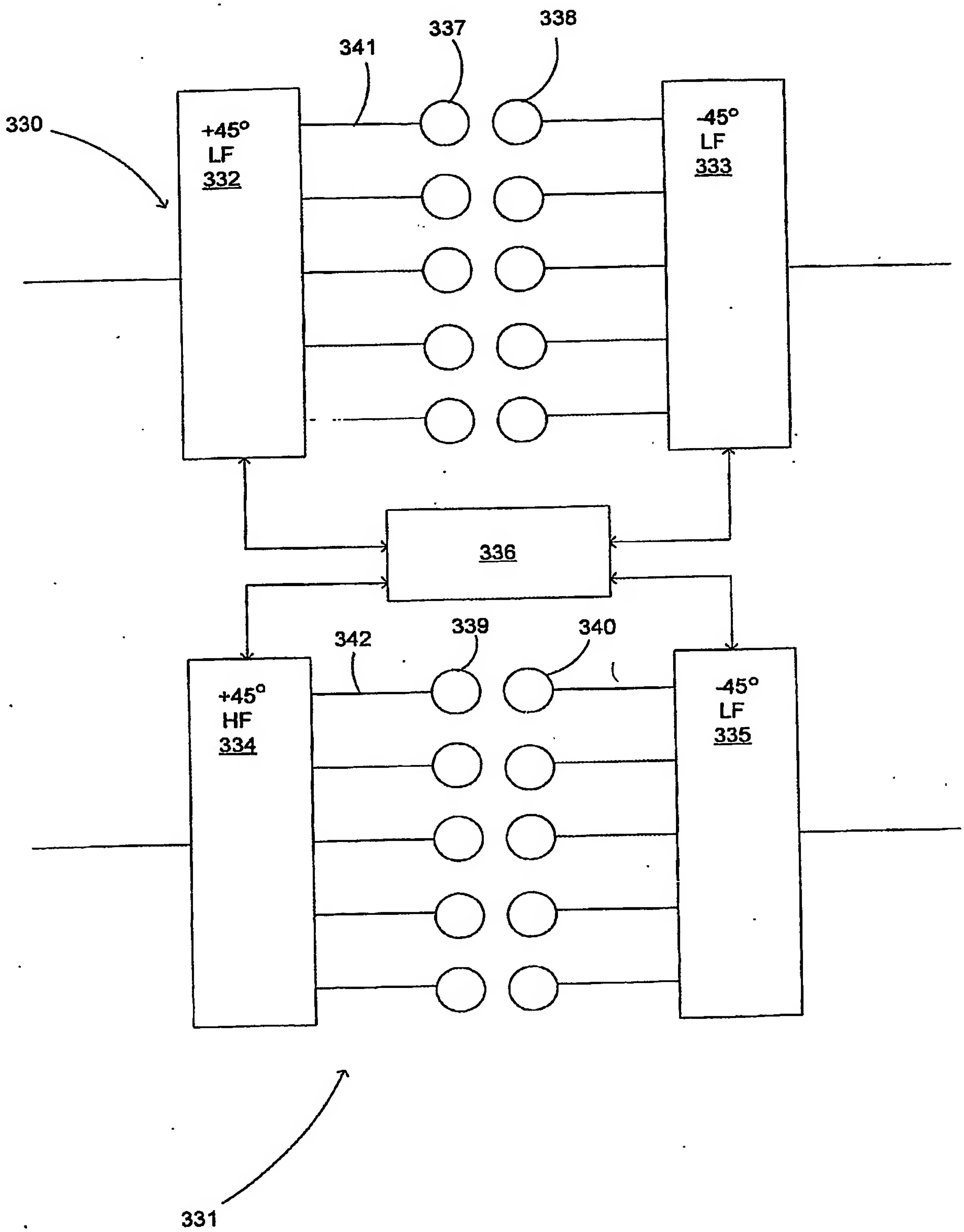
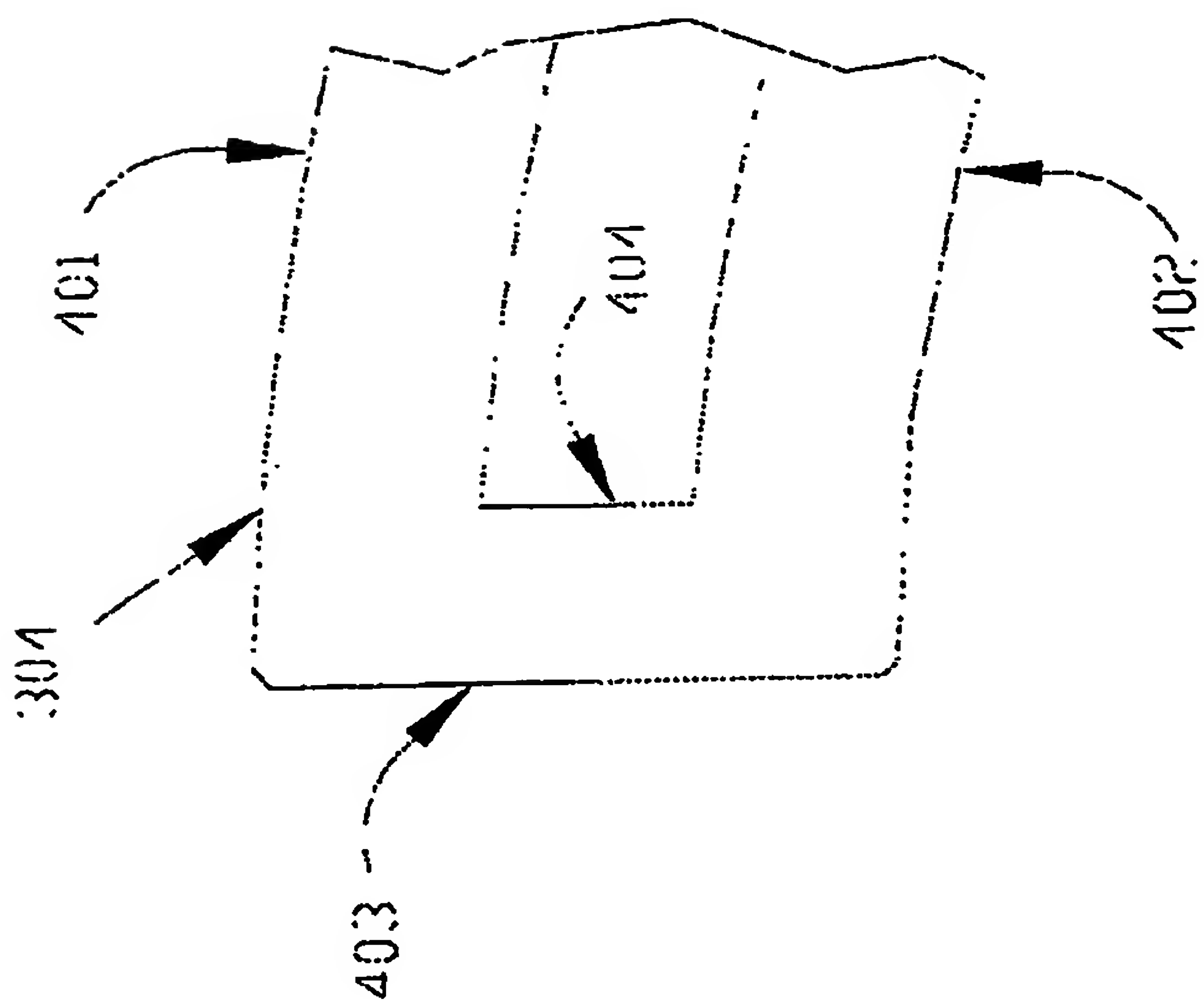


Figure 25

Figure 26


337
338
341
330
+45°
LF
332
-45°
LF
333
336
339
340
342
+45°
HF
334
-45°
LF
335
331



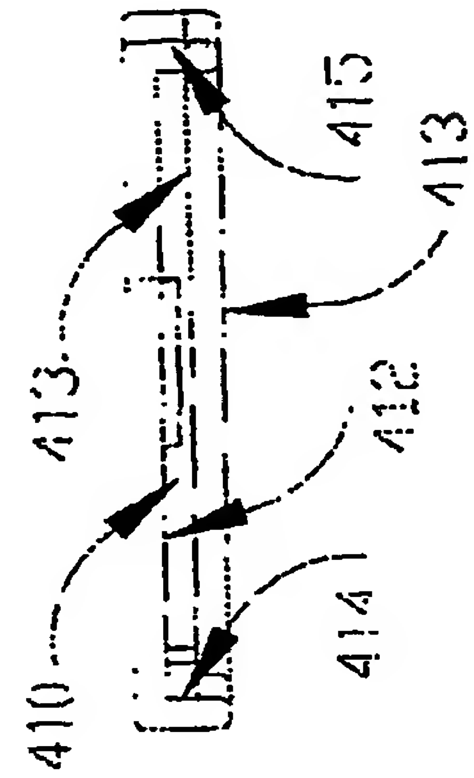


Figure 28

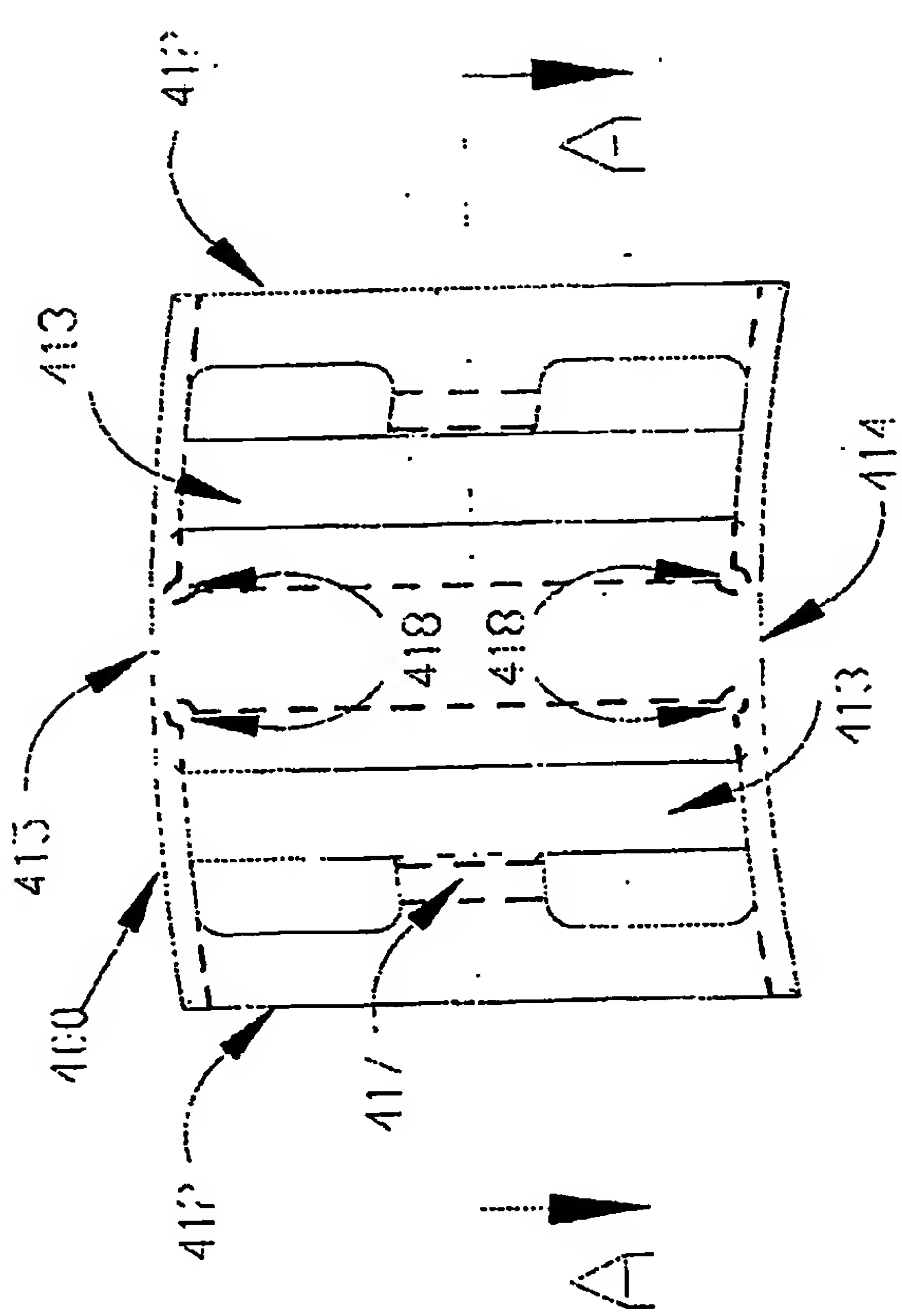
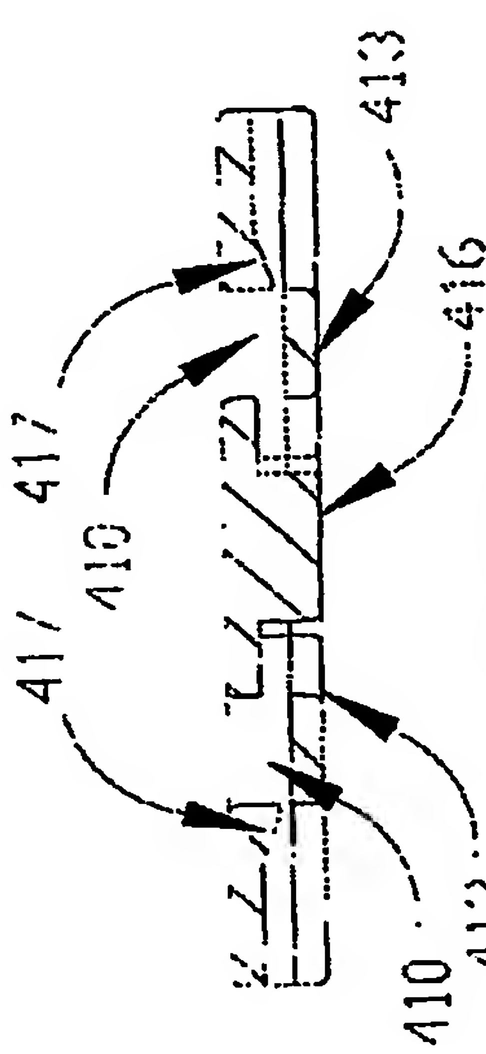


Figure 27



SECTION A-A

Figure 29